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PLASTIC CANOPY–A Computer Program for the Structural Analysis of Protective Canopies

By Kenneth D. Winters, Gary R. Gaven,
and James C. Ault

UNITED STATES DEPARTMENT OF THE INTERIOR

United States Bureau of Mines

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PLASTIC CANOPY-A COMPUTER PROGRAM FOR THE STRUCTURAL ANALYSIS OF PROTECTIVE CANOPIES

by

Kenneth D. Winters,[1] Gary R. Gavan,[2] and James C. Ault[3]

ABSTRACT

This Bureau of Mines report presents a Fortran IV computer program for the structural analysis of (1) protective canopies used in underground mines to protect equipment operators from roof falls and (2) rollover protective structures (ROPS) used in surface mines to protect equipment operators during vehicle overturn accidents. The program, entitled PLASTIC CANOPY, permits rapid and inexpensive calculation of the ultimate strength and deformation characteristics of a canopy for a variety of static loading conditions. The structure is modeled as a series of interconnected beam and/or plate elements. Stresses in, and displacements of, each structural element are computed and printed out at the yield strength of the canopy, at several intermediate load levels between the yield and ultimate strength of the canopy, and at the ultimate strength of the canopy. Other features of the program include prediction of buckling of a beam member under combined axial compression loading and bending, plotting of the input geometry of the structure, and plotting of the deformed shape of the loaded structure. Program description, input instructions, program listing, and four example problems are included.

INTRODUCTION

In 1972 the Bureau of Mines developed a computer program for the structural analysis of space-frame protective canopies. Entitled CANOPY,[4] this program was developed to provide mines installing canopies on existing equipment and manufacturers redesigning new equipment to include canopies with a method of determining that the canopy strength is "substantial," as required by the Federal Coal Mine Health and Safety Act of 1969. The CANOPY program permitted the rapid calculation of the elastic strength of a canopy modeled as a series of interconnected beam structural elements for a variety of static loading conditions.

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[4] Sawyer, S. G. CANOPY-A Computer Program for the Structural Analysis of Space-Frame Protective Canopies. BuMines IC 8546, 1972, 53 pp.

In 1974 The Mining Enforcement and Safety Administration (MESA)[5] established ROPS performance requirements for equipment used in the surface areas of coal mines. ROPS requirements for certain mobile equipment used in surface metal and nonmetallic open pit mines, in sand, gravel, and crushed stone operations, and in the surface areas of underground metal and nonmetal mines were established by MESA in 1977. A method for computing the ultimate strength of the ROPS was needed to meet the retrofit standards of the MESA requirements and to provide an effective analytical tool for designers of ROPS on new equipment.

To meet these needs, the CANOPY program was modified by Woodward Associates, Inc., under contract to the Bureau of Mines. The new program, entitled PLASTIC CANOPY, has five additional capabilities: (1) A plate element, (2) plastic beam analysis, (3) plotting routines, (4) buckling prediction for elastic beams, and (5) an improved solution routine.

Most canopies used on mining equipment have roofs covered with steelplate. Some cabs and canopies are fabricated with plates as major structural members. The addition of the plate element to the program enables the analyst to model these configurations more efficiently and accurately. Membrane and bending action of plates can be analyzed using plate elements of triangular or quadrilateral shape. Stresses are computed, and output for both upper and lower surfaces is determined at the centroid of the element.

Plastic beam analysis can be performed using plastic hinges in standard beam elements. Plate elements may be included in a plastic beam model but will remain elastic. This type of analysis is applicable to side loadings on ROPS, where ultimate load and absorbed energy are the important structural characteristics to be evaluated.

Plots of both deformed and undeformed geometries can be generated. They are useful as an input data check, and for observing deformation patterns.

The buckling routine can analyze a compression member including moment magnification due to axial load. A deflection curve computed for the member will diverge if the member is unstable under the combined bending and axial forces.

The last added feature is a new solution routine, which operates only on nonzero elements of the global stiffness equations and manipulates them in a blocked form. The blocked form enables the equations to be solved while using a limited amount of core storage.

In summary, the computer program PLASTIC CANOPY provides a practical method for evaluating the structural behavior of protective canopies. The program can be adapted to most computers. It is available to the general public by writing to The Technology Transfer Officer, Pittsburgh Mining and Safety Research Center, Bureau of Mines, 4800 Forbes Avenue, Pittsburgh, Pa. 15213.

---

[5] Now The Mine Safety and Health Administration (MSHA).

PROGRAM ELEMENTS

The PLASTIC CANOPY program has available beam, plate, and boundary elements for use in constructing a computer model of a structure. Characteristics of these elements and how they are to be used are discussed in the following sections.

Beam Element

A standard 3-dimensional beam element is used, with 3 rotational and 3 translational degrees of freedom at each node, giving a total of 12 degrees of freedom. The rotations correspond to a torsional moment (MX) about the member axis and bending moments (MY and MZ) about the principal axes of the cross section. Translational degrees of freedom correspond to an axial thrust (FX) and two shear forces (FY and FZ). The generalized forces corresponding to the beam element degrees of freedom are shown in figure 1.

Shear deformations, are included in the formulation of the beam element stiffness matrix, to assure accurate deformations for short, deep beams where shearing and bending deformations are of the same order of magnitude. The terms of the 12-by-12 beam element stiffness matrix are shown in appendix A.

A local coordinate system is assigned to each beam element, with the origin at node J. This right-handed, orthogonal coordinate system shown in figure 2, is defined as follows: X_m is directed along the member axis, through the centroid of the cross section, from node J to node K (J less than K);

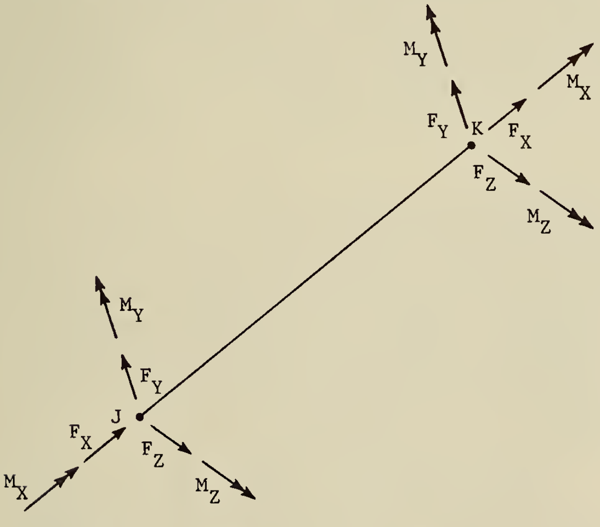


FIGURE 1. - Generalized forces corresponding to beam element degrees of freedom.

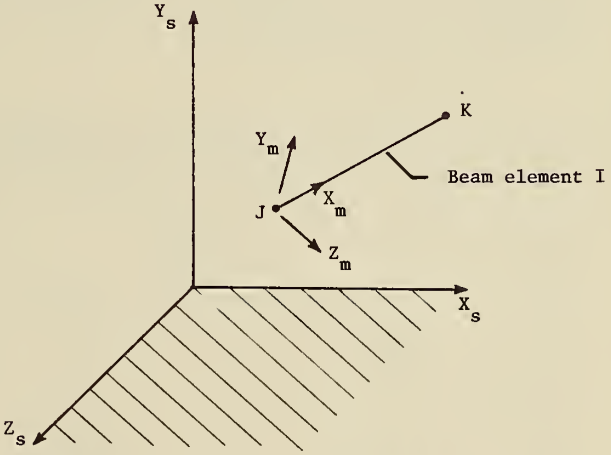


FIGURE 2. - Local coordinate system, beam element I.

Z_m lies in a plane parallel to the X_s-Z_s plane, where subscript s denotes global or structure coordinates; Y_m is perpendicular to both X_m and Z_m. For the case where the X_m axis parallel to the Y_s axis, the Z_m axis parallel to the Z_s axis.

Section properties are computed, in local coordinates, for all beam elements with one of the following regular cross-sectional shapes: I-beam, solid circular or rectangular shapes, and circular or rectangular tubes. For irregular cross sections, properties must be directly input.

The properties are computed in subroutine PROP and include cross-sectional area (AX), torsional moment of inertial (IX), bending moments of inertia (IX and IY), distance to extreme fibers (ACX, ACY, ACZ), shape factor for shear deformation (F), and plastic bending modulus (BM).

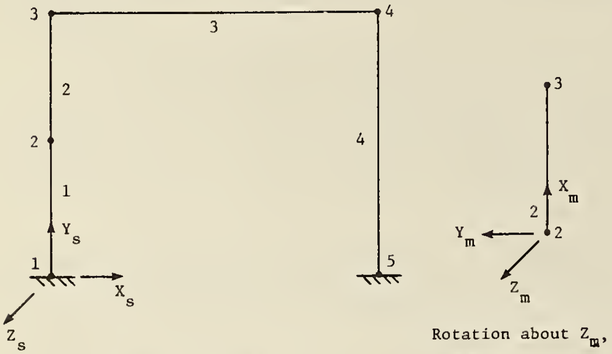
Internal Hinge

A modification to the standard beam element described above is available for cases where a bending moment cannot be transmitted through a specific joint. It is useful, for example, when modeling a ROPS mounting socket that is pinned about one axis, but is located within the structure rather than at a boundary joint.

Appropriate rotational degrees of freedom can be deleted from a beam element to simulate this condition. For example, if, in the structure shown in figure 3, bending moment about the axis Z_s cannot be transmitted through node 2, the corresponding degree of freedom can be deleted from beam element 2. The deleted degree of freedom is in the local, or member, coordinate system; thus the rotation about Z_m is deleted from beam element 2 at node 2. Note, however, that the global and local axis for the deleted degree of freedom will not always be the same.

The rotational degree of freedom is removed by static condensation of the element stiffness matrix;[6] this process is explained in appendix B. After condensation, the element stiffness matrix will have a row and column of zeroes corresponding to the deleted degree of freedom. When the structure equations are solved for global displacements, a rotational discontinuity exists at the point of the internal hinge.

The rotation printed by the program will be for the part of the structure exclusive of the member with the internal hinge; the discontinuity will be the relative rotation of the member



M_Z=0 at node 2

Rotation about Z_m, deleted at node 2

FIGURE 3. - Example structure, internal hinge at node 2.

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[6] Cook, R. D. Concepts and Applications of Finite Element Analysis. John Wiley & Sons, Inc., New York, 1974, 402 pp.

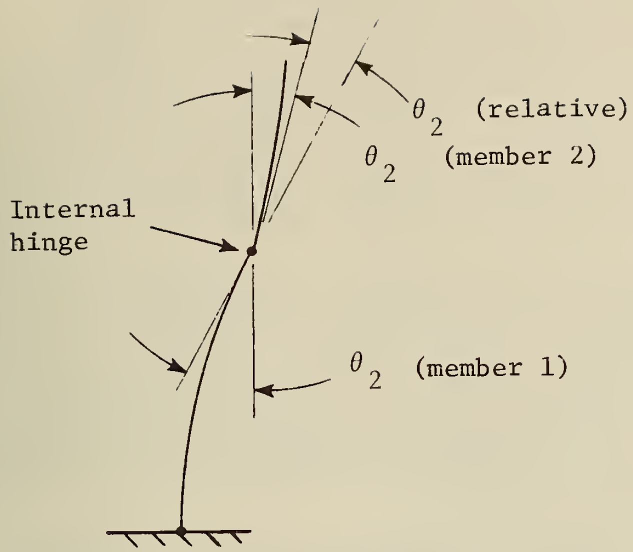


FIGURE 4. - Rotations at internal hinge in a beam element.

with the hinge to the remainder of the structure. In the example shown, the Z_s rotation in the printed output for node 2 will be rotation of that node in element 1 as shown in figure 4. The rotational degree of freedom could also have been deleted from beam element 1; in that case the printed output would give the rotation in element 2.

A rotational degree of freedom is released in a beam member by designating the appropriate degree of freedom on the beam element designation card.

Plate Element

PLASTIC CANOPY has a flat plate element[7] that can model both membrane and bending action. The basic element is a quadrilateral of arbitrary shape, shown in figure 5. Interior node 0 is located at the average of the coordinates of the exterior nodes I, J, K, and L. This node defines a vertex common to the four triangular subelements a, b, c, and d. A triangular element may also be defined, for which no internal node is assigned.

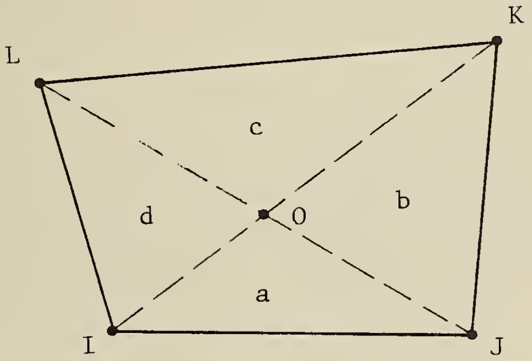


FIGURE 5. - Quadrilateral plate element and triangular subelements.

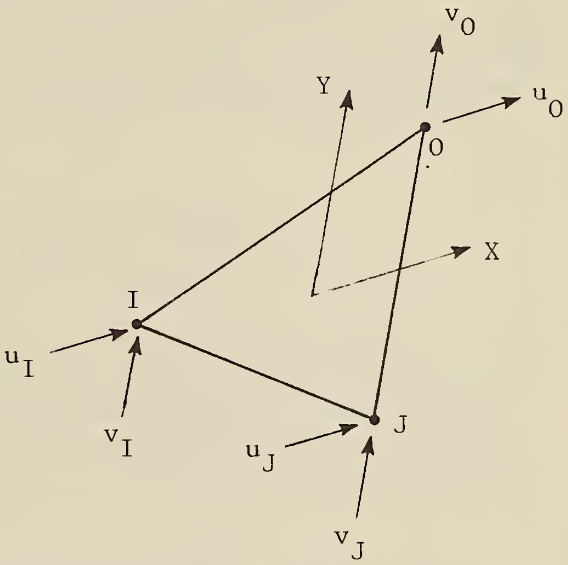


FIGURE 6. - Membrane degrees of freedom for a triangular subelement.

---

[7] Clough, R. W., and C. A. Felippa. A Refined Quadrilateral Element for Analysis of Plate Bending. Proc. 2d Conf. on Matrix Methods in Structural mechanics, Wright Patterson AFB, Ohio, 1968.

Each node (including the interior node of a quadrilateral) has five degrees of freedom: Two inplane translations (fig. 6) define the membrane action, and a transverse displacement w and two rotations θ_x and θ_y (fig. 7) define the bending action. Rotation about an axis perpendicular to the plate surface at a node is not defined as a degree of freedom. Diagonal stiffness terms for these degrees of freedom are taken as 1 to avoid singularities in the global stiffness matrix. To allow compatibility with beam elements, a plate element node is assigned the full set of six degrees of freedom.

Within a triangular subelement, subregions are formed that are also triangular, as shown in figure 8. Stiffness contributions are computed in area coordinates for each subregion, and the three subregion contributions are combined to form a subelement stiffness matrix. A quadrilateral element is formed by summing 4 triangular subelements and eliminating the 5 degrees of freedom at the interior node by static condensation, resulting in a 4-node, 20-degrees-of-freedom element. A triangular element is formulated by summing its three subregions; no condensation is necessary.

Local coordinates are assigned to each quadrilateral, as shown in figure 9. The local x-axis passes through the midpoints of sides L-I and J-K. The z-axis is perpendicular to the line connecting the midpoints of sides I-J and K-L and also to the x-axis. For a flat plate, the Z-axis is perpendicular to the plate's surface. The y-axis is mutually perpendicular to the x- and z-axes in a right-handed system; it does not necessarily coincide with the line between the midpoints of sides I-J and K-L.

For a triangular element, the local coordinate system is shown in figure 10. The x-axis passes through node I and the midpoint of J-K, z is perpendicular to the element surface, and y is perpendicular to the x and z axes. The origin is on the line bisecting sides I-J and K-I.

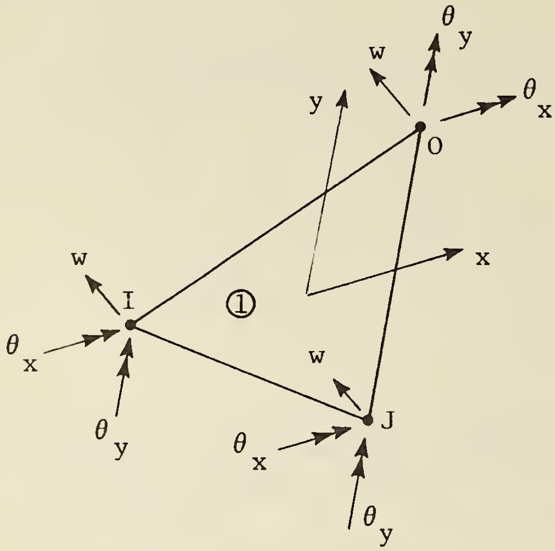


FIGURE 7. - Bending degrees of freedom for a triangular subelement.

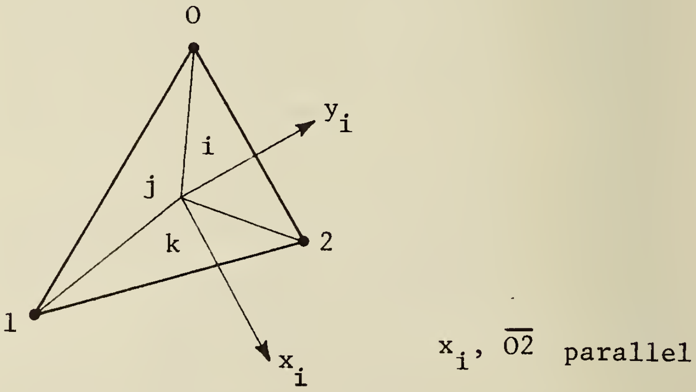


FIGURE 8. - Subregions of a triangular subelement.

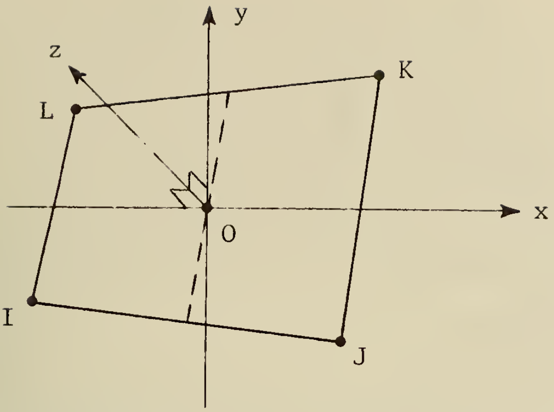


FIGURE 9. - Local coordinate system, quadrilateral element.

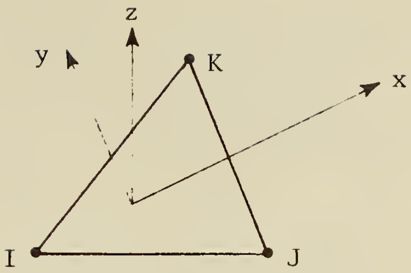


FIGURE 10. - Local coordinate system, triangular element.

Membrane and bending stresses are computed and printed out for each plate element in its local coordinate system.

Displacement Functions

The inplane translations for membrane action within a triangular subelement are assumed to be described by equation 1:

$$u = C_1 + C_2 x + C_5 y$$

$$v = C_4 + C_5 x + C_6 y. \tag{1}$$

This displacement field gives constant strains within an element, has interelement compatibility, and will converge monotonically as the mesh size is refined.

Bending action is described by a third-order polynomial,

$$w = C_7 + C_8 x + C_9 y + C_{10} x^2 + C_{11} xy + C_{12} y^2 + C_{13} x^3 + C_{14} xy^2 + C_{15} y^3, \tag{2}$$

where the term for $x^2 y$ is missing from a complete third-order expansion. This allows the normal slope along the exterior edge of a triangular subelement to vary linearly. The displacement w and its first derivatives are continuous within a triangular subelement. Bending displacements are compatible between adjacent elements. Clough and Felippa refer to the bending element as the LCCT9 element.[8]

Beam-Plate Compatibility

When a beam element and plate element have a common node, there is an incompatibility between the two elements. This is due to the fact that a beam element has six degrees of freedom per node, while a plate element has five degrees of freedom per node.

---

[8] Work cited in footnote 7.

Consider, for example, the structure of figure 11, where element 1-2-3-4 is a plate element and 1-2, 3-4 are beam elements. At each node the rotational degree of freedom about the y-axis is defined in the beam elements, but not in the plate element. The y-axis rotation at each node is then defined by the stiffness of the beam elements, with no contribution from the plate element. Figure 12 shows a possible displacement configuration of the example structure, where θ_1 is determined by the stiffness of the beam element 1-2. The three translations and rotations about the X and Z axes (in the example) are compatible between the beam and plate elements.

Boundary Element

A boundary element provides a method of fixing a structure in space. For a node point attached to an exterior support, a boundary element is defined for each displacement of the affected node that is to be restrained. It can be applied to some or all of the six degrees of freedom at the node, in global coordinates.

The program applies a stiffness coefficient of 1×10^{20} to the diagonal element of the global stiffness matrix; this is several orders of magnitude greater than a typical diagonal element resulting from beam and/or plate stiffness. This element is sufficiently large to represent a fixed-boundary condition; that is, no deflection will occur at a degree of freedom with a boundary element applied.

Figure 13 shows boundary elements applied to the translational degrees of freedom at node 1.

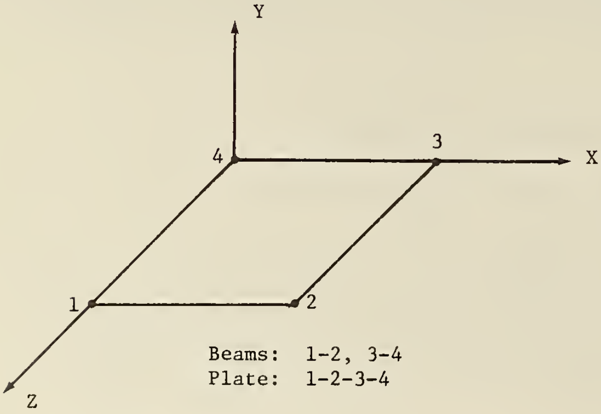


FIGURE 11. - Example structure with beam and plate elements.

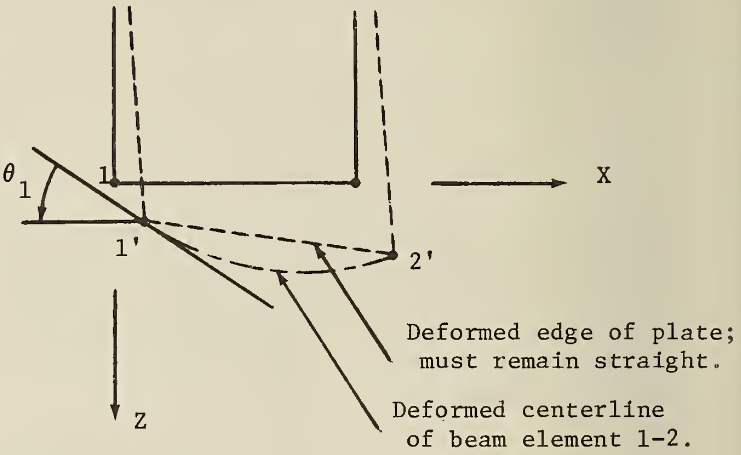
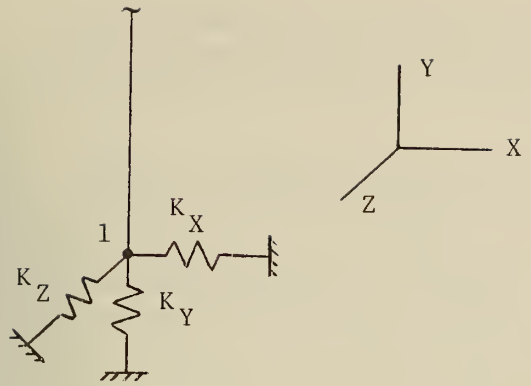

θ1
1
1'
2'
X
Z
Deformed edge of plate; must remain straight.
Deformed centerline of beam element 1-2.

FIGURE 12. - Displacement configuration for beam-plate structure.

ANALYSIS MODES



$K_X = K_Y = K_Z = 1 \times 10^{20}$ lb/in

FIGURE 13. - Boundary elements applied to translational degrees of freedom.

The PLASTIC CANOPY program can operate in either a plastic or an elastic mode. In the elastic mode, a structure made of beam elements, plate elements, or a combination of the two is analyzed by the stiffness method of structural analysis, yielding nodal displacements for a given set of loads. In the plastic mode, a structure composed of beams or beams and plates is analyzed to its ultimate capacity by a series of elastic steps. The end of each step is marked by the insertion of "plastic hinges" in the appropriate beam(s) that have yielded, followed by reformulation of the structural equations. For a structure composed of only plate elements, the plastic option is not available. Beam buckling and plotting options are available in both elastic and plastic modes; in the plastic mode buckling computations are based on the load level corresponding to the elastic limit of the structure.

Elastic Analysis

The stiffness method of structural analysis is used to obtain an elastic solution of a problem. This method is widely known and extensive treatments are available in several textbooks.[9]

The basic equation of the method is

$$[K]\{D\} = \{R\}, \tag{3}$$

where K = global stiffness matrix,

D = nodal displacement vector,

and R = nodal load vector.

$[K]$ is computed from the summation of all element stiffness contributions, and $\{R\}$ is obtained from the load input data; solution requires finding the displacements $\{D\}$.

PLASTIC CANOPY will proceed through the following series of steps to effect an elastic solution of a structural analysis problem:

1. Construct the computer model as an assemblage of nodal points interconnected with beam and/or plate elements, fixed in space by boundary elements.

---

[9] Work cited in footnote 6.

2. Assemble the overall structure stiffness matrix [K] by combining the contributions of all the beam, plate, and boundary elements. This matrix represents equilibrium equations of the six degrees of freedom at each node.

3. Apply a loading {R} to the structure; this can be input as nodal point loads, uniform loads on beam elements, or uniform pressure on plate elements.

4. Solve the global stiffness equation 3 to obtain the nodal displacements {D}.

5. Using nodal displacements, compute element stresses.

Solution of the equations in step 4 uses Gaussian elimination to invert the positive-definite symmetric stiffness matrix [K] of equation 3. A minimum number of operations are performed; that is, there are no operations with zero elements. In the program, the $L^T DL$ decomposition of [K] is used; hence equation 3 can be written as

$$L^T v = R, \tag{4}$$

and

$$v = DLu \quad (u = \text{displacements}), \tag{5}$$

where the solution for v in equation 4 is obtained by a reduction of the load vector; the displacement vector u is when calculated by back substitution.

Equations are brought into high-speed (core) storage in a blocked format, requiring only a portion of the total set of global equations to reside in core at one time. The size of a block is determined in the routine CANOPY/V2 by the size of the unlabeled common block C (xxxx) and the variable MTOT. Block size can be altered by changing these two items.

A large block size will require a greater amount of core storage but a lesser amount of low-speed data manipulation; a small block size requires less core storage but more manipulation of low-speed data, since more blocks are required to contain the entire set of equilibrium equations. The size of a block can be adjusted to take advantage of accounting schedules at a partiticular facility--a large block size can be used if core storage is inexpensive relative to low-speed data manipulation, and a small block size can be used if the opposite case holds. The current block size, with MTOT = 3,000, is 1,500 locations, MTOT being two times the size of one block, as is the blank common block C (3,000).

No maximum allowable bandwidth is imposed on the set of equations described by equation 3. A larger bandwidth will mean more blocks are needed to contain the same number of equations, but the number of operations will remain essentially the same. An optimally numbered structure will require fewer blocks than a poorly numbered structure, and the difference in computing time will be due to the extra manipulation of the low-speed storage data.

Characteristics of the program in the elastic mode that depend on the type of element(s) used in a model are explained in the following sections.

Beam Elements

For a structure with beam elements only, the magnitude of the input load is arbitrary, as the program will ratio all quantities to the level where the highest stressed point within the structure has just begun to yield. The von Mises effective stress is used as the criterion for the start of yield. Stresses are computed at the endpoints of beams only; for a member with a uniform loading, a node point located at the middle of the loaded member will assure checking the stress where the maximum bending moment due to the uniform loading occurs.

Axial stress (SIGAX) is computed by dividing the axial force on a member by its cross-sectional area. The maximum bending stresses about the Y_m and Z_m axes are calculated from the expressions MY*ACY/IY and MZ*ACZ/IZ, respectively, where MY and MZ are bending moments, IY and IZ are moments of inertia, and ACY and ACZ are distances to extreme fibers. The two bending stress components are added to give the total bending stress, SIGBMX. SIGBMX and SIGAX are added to give SIGMAX, the maximum stress along the X_m axis of a member.

For solids and tubing that are circular, maximum torsional stresses (TAUMAX) are computed from the expression MX*ACX/IX, where MX is the torsional moment, IX is the torsional moment of inertia, and ACX is the outside radius. For other types of members, maximum torsional stresses are approximated. In rectangular or square structural tubing, torsional stresses are assumed to be uniformly distributed across the thickness and are found from the expression MX/2At, where t is the smaller of TF and TW, flange and web thicknesses, respectively, and A is the total area enclosed by the tube cross section. The expression CMX/ab^2 gives the maximum torsional stress in solid, rectangular shafts, where a is the larger of B and H, the width and heighth of the section, respectively, b is the smaller of B and H, and C is a function of a and b. The calculation of torsional stress in I-beam members is the most difficult. For these members, only pure torsional shear stresses in the flanges are computed and are given by MX*TF/IX.

SIGMAX and TAUMAX on a member end are rotated to give the principal stresses SIGMA1 and SIGMA2. SIGMA1 and SIGMA2 are used to compute the effective stress (VMISES) as given by the von Mises yield criterion. When the effective stress reaches the member's elastic strength, yielding has begun. After an elastic analysis, the ratio of effective stress to yield stress (VMISES/ALLOW) along with SIGBMX, SIGAX, TAUMAX, SIGMAX, SIGMA1, SIGMA2, and VMISES is printed out at the endpoints of each member. The ratio VMISES/ALLOW will be 1.0 for the highest stressed point (beam endpoint) in the structure.

Plate Elements

Structures modeled with plate elements only will be solved for the applied magnitude of loading. Factoring to raise or lower the load to a yield level is not done as it was for the beam elements.

Stresses are computed for a state of plane stress by the equation

$$\begin{Bmatrix} \sigma_{xx} \\ \sigma_{yy} \\ \tau_{xy} \end{Bmatrix} = \frac{1}{1 - \nu^2} \begin{bmatrix} E & \nu E & 0 \\ \nu E & E & 0 \\ 0 & 0 & (1 - \nu^2)G \end{bmatrix} \begin{Bmatrix} \epsilon_x \\ \epsilon_y \\ \tau_{xy} \end{Bmatrix}, \qquad (6)$$

where E = Young's modulus,

G = shear modulus,

and ν = Poisson's ratio.

Subscripts x and y refer to element coordinates as previously defined. For membrane action, the strain vector is computed as a function of the inplane translations of the node points; for bending action, it is computed as a function of the transverse displacement and rotations at the nodes.

A restriction is imposed on the use of uniform pressure loads applied to plate elements. If a pressure is applied with multiple load cases, the pressure will be identically applied on each of the loadings; it cannot be applied on one load case and removed on the next. However, to avoid this, the uniform loading can be simulated by dividing the pressure equally among the nodes of the loaded elements and applying it as point loads.

Plate and Beam Elements

When a combination of elements is present, the applied loading will be ratioed to the point where the highest stressed beam element has reached the material yield stress. The load at this level may be great enough to have yielded some of the plate elements.

Stress computation for the respective elements proceeds as described in the above sections.

A warning is printed whenever the von Mises stress in a plate exceeds 36,000 psi; it is printed immediately after the table of plate element principal stresses. If this warning is present, the user should evaluate the results closely to see how the plastic behavior of the plate, not considered in the program, would alter predicted stresses and deformations. Obviously, for plates with a higher yield stress, this warning is not effective until the higher stress level is reached.

Plastic Analysis

A plastic, or limit, analysis[10] of a structure composed of beam or beam and plate elements consists of a sequence of elastic steps, each carried out in a manner identical to that described in the prior section on elastic analysis.

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[10] Work cited in footnote 6.

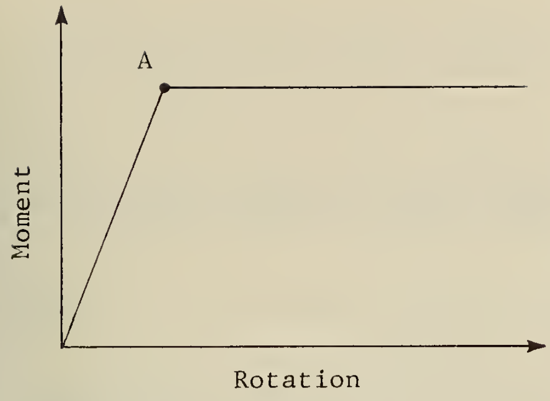


FIGURE 14. - Elastic-perfect plastic material response curve.

At the termination of each step, plastic hinges are inserted endpoint(s) of a beam element(s) where a yield criteria has been satisfied. Application of a hinge will result in the condensation (see appendix B) of the three rotational degrees of freedom at the hinge point. The overall structure equations are then reassembled, with the appropriate beam element stiffnesses modified for the applied hinges. Hinges will continue to be added to the structure until a mechanism forms and the structure becomes unstable or a specified deflection limit is reached.

Plastic behavior in three dimensions is a highly complex phenomenon and is approximated in PLASTIC CANOPY by beam elements capable of developing plastic hinges at one (or both) endpoints(s) characterized by the following assumptions:

1. The behavior of a beam endpoint is either elastic or plastic; this is shown in figure 14, where a hinge is inserted at point A of the moment-rotation response curve. The behavior shown applies to bending moments about both principal axes and the torsional moment. All three moments undergo the transition denoted by A at the same external load level.

2. The transition at point A occurs when the effective (von Mises) stress at a beam endpoint reaches the material yield stress; contributions to this stress are from the two bending moments, the torsional moment and axial force. Bending stresses are allowed to reach yield over the entire cross section; thus developing the fully plastic moment described in appendix C before making the transition.

3. The region of plastic behavior is restricted to beam endpoints; growth of the yielded region upon further loading is neglected.

4. The torsional and bending moments at a hinge remain constant throughout subsequent load steps; axial stress is allowed to increase with further loading.

In a plastic analysis, the program will proceed through a series of steps similar to those followed in an elastic analysis. The entire series is repeated as many times as are required to cause structural instability or meet a user-specified deflection limitation. The sequence of steps follows:

1. Define the structure (nodes, beams, plates, etc.)

2. Assemble the overall stiffness matrix [K] as a summation of all member stiffness matrices.

3. Applying a loading {R}.

4. Solve the equation [K] {D} = {R}, obtaining joint displacements {D}.

5. Compute element stresses.

6. Insert hinge(s) in beam element(s) with highest stress; if more than one beam element has nearly the same stress level, several hinges will be inserted simultaneously.

7. Check for structural instability or deflection limitation, and terminate run if satisfied; otherwise repeat steps 2 through 6.

Both methods of program termination in step 7 will yield the same value (or very nearly the same) for the ultimate load, but quite different values for the energy absorbed. This is shown in figure 15, where automatic termination will occur at point A, but a user input deflection limitation of D_B will cause termination to occur at point B. The final load P is the same in both cases, but the absorbed energy (area under curve) is much greater in the second case. Thus, if a user wants a realistic estimate of the absorbed energy, a deflection limitation should be applied to cause termination at B rather than at A.

The magnitude of the applied loads on user-prepared input cards is arbitrary, since the program will automatically ratio all quantities to the load level where hinges form, or the program terminates. All entries in the vector {R} are uniformly factored. If a beam element has a uniformly distributed loading applied, and a hinge forms at one of its endpoints, the set of equivalent nodal loads for that member is appropriately modified.

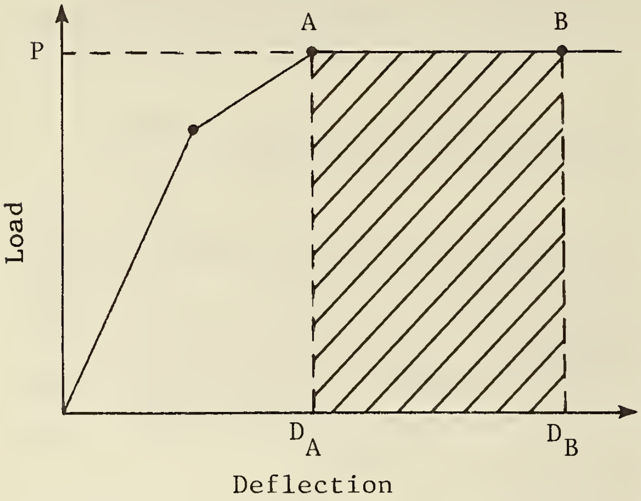


FIGURE 15. - Alternate termination points for a plastic analysis.

Plate Elements

It is possible to do a plastic analysis of a structure composed of both beam and plate elements. However, it is important to realize that the plate elements can only represent elastic behavior; the only plastic behavior is represented by the plastic hinges in beam elements. Thus in successive load increments, the plate elements will continue to make the same contribution to the overall structure stiffness. If a plate element should begin to yield, the plate stiffness will not be properly reduced to reflect this fact.

Plate stresses are printed after the final step of a plastic analysis and are based on the cumulative displacements of all the load steps. A warning is printed if the effective stress in any plate exceeds 36,000 psi. If a higher-yield-strength plate is used, this warning should be acknowledged only when the higher stress is exceeded. When a plate does exceed yield in a plastic analysis, the user must assess the magnitude of excess strength given the structure by the plate and make an approximate compensation for it, or reformulate the problem without the plate elements.

Buckling

The buckling routine will check beam members under axial compression for instability. Member forces found from the elastic solution of a structure are used as the basis for the buckling calculations. The unit-load method[11] is used to compute all required deflections along a buckling member, which may consist of one or more beam elements.

Buckling members are designated in the program by the nodal numbers of their endpoints and are read as input data by the program. If the axial force in a buckling member is tensile, or less than 15 percent of the Euler critical load, the member is not checked for buckling. The 15 percent of critical is taken as the load which, if exceeded, causes deflections (and moments) along the buckling member to be significantly increased by the axial force.[12]

In the unit-load method, the integral of equation 7 is evaluated to determine a deflection along the member of figure 16.

$$\Delta Y_A = \int_0^L \frac{Mm}{EI}\,dx, \qquad (7)$$

where ΔY_A = deflection in Y direction at point A,

M = moment along the buckling member due to the applied loads,

m = moment along the buckling member due to a unit load at A,

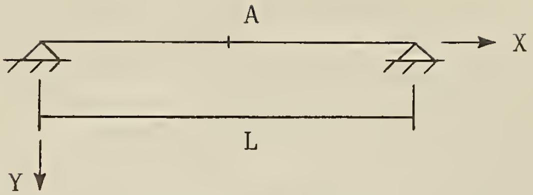
x = coordinate along member axis,

and EI = bending stiffness of the member.

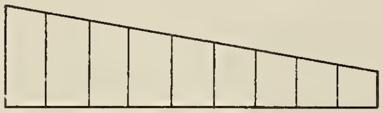
---

[11] Wang, C. K. Statically Indeterminate Structures. McGraw-Hill Book Co., New York, 1953, 424 pp.

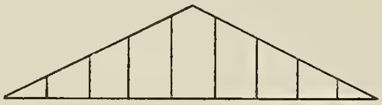
[12] Roark, R. J., and W. C. Young. Formulas for Stress and Strain. McGraw-Hill Book Co., New York, 1975, 624 pp.



Buckling member



Moment diagram due to external loads



Moment diagram due to unit load at A

FIGURE 16. - Moment diagrams used in unit-load method.

For a given buckling member, the M curve is obtained from the elastic solution of a structure, and the M curve is computed in the subroutine BUCKLE for any location A. The integral is approximated by equation 8, dividing the length L into NINCR increments of length ΔL, and taking the values of M and m at the midpoints of each interval.

$$\Delta Y_A \cong \sum_{n=1}^{NINCR} \frac{M_i m_i}{EI} \Delta L, \tag{8}$$

The input required for a buckling member is the two endpoints (NEP1, NEP2) and the member numbers of the beam members containing these two points (NM1, NM2). For a buckling member consisting of only one beam element, NM1 = NM2.

The step-by-step procedure used by the program to compute a deflection curve for a buckling member follows:

1. Obtain an elastic solution of a structure, giving the displacements of each node.

2. Using the member stiffness matrix of beam element NM1 and the nodal displacement array for element NM1, obtain the member forces at point NEP1.

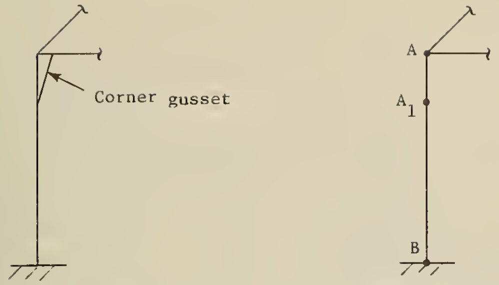
3. The array of forces in step 2 yields a moment curve M along the buckling member, and the axial force.

4. If the axial force is tensile or less than 15 percent of the Euler critical load, do not proceed further with this buckling member.

5. Using the moment curve in step 3 and the unit load method, compute the deflection curve along the buckling member.

6. Increase the moment curve of step 3 by including the effect of the axial force times the lateral deflection of step 5.

7. Repeat step 5, but this time use the moment curve from step 6. Continue repeating steps 5 through 7 for as many iterations as are required to show a diverging deflection curve, or for NITER iterations if the curve does not diverge (NITER = 25).



Structural element

A_1B as a buckling member

FIGURE 17. - Buckling member.

For the case of an unstable buckling element, the deflection curve found in step 5 will get increasingly larger with each step. The deflections diverge to infinitely large values, and the program output gives a message saying the member has buckled.

If the member is stable, the deflection curves found in step 5 will converge to a finite value. This deflection curve represents a state of equilibrium, where the effect of the axial force on the deflected shape is included. In this case, moments including the axial effect, and a von Mises-over-yield (VMISES/YIELD) ratio are computed for the buckling member.

The moment diagram m used in the unit load formula, equation 7, assumes a pinned connection at both ends of the buckling member. Although this is not always consistent with the end conditions of an actual buckling member, the effect on the buckling prediction is minor. With inconsistent end conditions, the magnitude of the computed deflections will be slightly overestimated, but the convergence or divergence of the deflection curve is not dependent on this magnitude. Thus the decision on whether or not the member buckles is not affected, and for the unbuckled case the computed stress will be slightly overestimated. If the end conditions of the buckling member are pinned, then the exact deflection curve, including axial effect, will be computed.

An example of a buckling element is shown in figure 17 where, due to the corner gusset, the member A_1B is a more realistic designation of a buckling element than AB.

Plot Package

The plotting routines generate two-dimensional projections of three-dimensional structural models composed of beam and/or plate elements. Undeformed and deformed geometries can be plotted, either superimposed on the same frame or on separate frames.

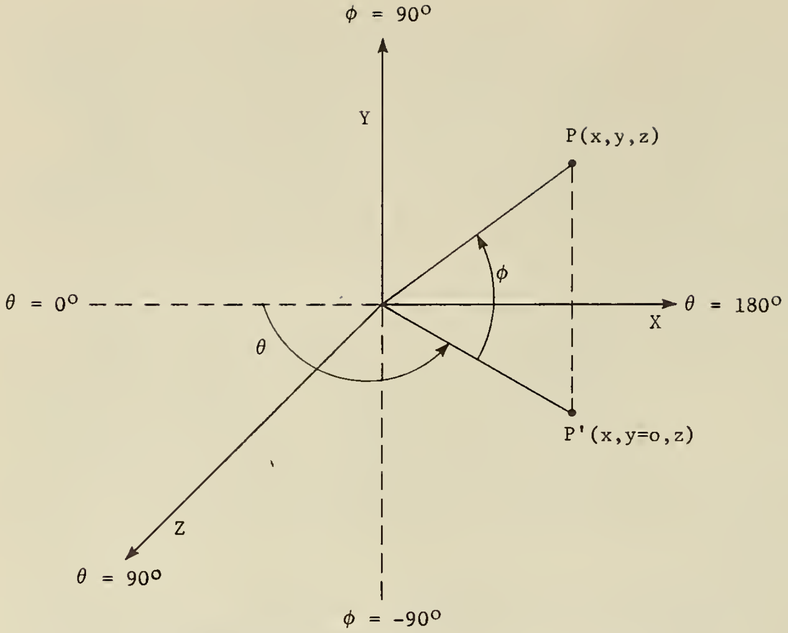


FIGURE 18. - Plotter orientation angles.

Each node is resolved onto a two-dimensional plotting surface, perpendicular to an optic axis which passes approximately through the center of the structure and is oriented relative to the structure by the angles THETA and PHI. These two angles are shown in figure 18. The angle THETA tends to determine which face of the structure will be nearest the viewer, and PHI determines whether the top or bottom surface will be shown. Values for THETA and PHI can be directly input by a user, or can default to $\theta = 120°$, $\phi = 30°$. With PHI between +30° and -30°, a minimal amount of distortion will be present in the plot; THETA can range from 0° to 360°.

When superimposing a deflected shape onto an undeflected shape, a magnification factor, DMAG, is available which will uniformly increase all translational deformations, making the deformed plot more visible. The factor should be used on elastic runs unless very high deflections are expected, in which case it is not necessary. On plastic runs with a user-specified deflection limitation, it is not needed; without a user-specified deflection limitation, it is useful in some cases but is usually not needed. A value of DMAG in the range 3 to 10 will be sufficient for most elastic runs. Furthermore, deflected shapes generally will show more clearly a loading pattern when superimposed over the undeflected shape, rather than plotted on a separate frame. The character "o" is used to mark undeformed nodes; "*" is used to mark deformed nodes.

When plotting a two-dimensional structure, it is required to have "depth" in the Z direction of the structure in order to properly scale the plot. This can be achieved either by locating the structure in the Y_s-Z_s or X_s-Z_s planes (not the X_s-Y_s plane) as defined by the global structure axis system, or by locating it in a plane that is not parallel to any of the three principal planes.

Call Sequence

The plotting routines are called from CANOPY/V2 with the following call statement:

```
CALL PLOTS (IADV, NJ, M, NUMPL, X, Y, Z, JJ, JK, THETA, PHI, TITLE, ANGL)
```

where IADV = frame advance (if IADV = 0, advance frame; if IADV = 1, do not advance frame),

NJ = number of joints,

M = number of beam elements,

NUMPL = number of plate elements,

X, Y, Z = arrays of nodal coordinates (deformed or undeformed),

JJ, JK = arrays of beam element endpoints,

THETA, PHI = orientation angles,

TITLE = structure title, printed along bottom of plot,

and ANGL = array to print orientation angles below title.

This package, currently operational on Gould plotters, can be easily adapted to a Calcomp plotter, with the following modifications. The raster count limits, statements 76-79 of subroutine PLOTS, must be set to reflect the larger size of the plot. For a Calcomp, limits of IL=100, IR=1800, JB=130, JT=1900 should be satisfactory. In addition to the raster count limits, the third argument in SETUPV must be changed from 'MUST GOULD' to 'MUST CALCOMP', at statement 170 of subroutine PLOTS.

Plot Subroutines

The plotting routines (PLOTS, PLOTIT) make use of several standard graphics library routines to generate the required graphics file. The routines and their functions follow:

1. SETUPV--setup routine to activate plotting, usually unique to each computer installation.

2. FRAMEV--frame advance routine.

3. PLOTCV--routine to plot a specified character; plots "o" for undeformed node points and "*" for deformed node points.

4. LINEUV--routine to draw a line between two points.

5. MODEV--routine to convert user (X_s, Y_s, Z_s) coordinates to raster coordinates.

6. TYPEV--routine to type a line of printed information on the plot.

7. FINSHV--routine to close out the graphics file; usually unique to a particular installation. Called from CANOPY/V2, immediately prior to program termination.

The above plot library routines or their equivalent must be available to the plot package. If equivalent routines are available but under different names, the above names must be replaced with the proper ones wherever they appear in subroutines PLOTS and PLOTIT. The variables in the call statements of the above routines are noted on comment cards in the two subroutines.

PROGRAM ORGANIZATION

The PLASTIC CANOPY program consists of a driver routine, CANOPY/V2, and 27 subroutines. Some of the subroutines act as subdrivers, to control certain distinct phases of the overall problem solution. The subdrivers are all called from the main driver, CANOPY/V2. They are listed, with their functions, in table 1.

TABLE 1. - Subdrivers and their functions

Subdriver	Function
SOLVE.............	Controls assembly and solution of the structure stiffness equations.
TPLATE............	Builds local stiffness for plate elements.
STRESS............	Computes and prints out plate element stresses.
PLOTS.............	Creates graphics file for plots of deformed and undeformed geometry.

In table 2, the driver and the four subdrivers are listed, with the subroutines called by each.

TABLE 2. - Driver and subdriver calls

Sub or main driver	Called subroutines
CANOPY/V2 (main).......	PROP, SOLVE, BOUND, BEAM, TPLATE, BUCKLE, PLOTS, STRESS.
SOLVE (sub)...........	CALBAN, ADDSTF, INL, USOL, PRINTD.
TPLATE (sub)..........	STRETR, CSTSTR, LCT9ST, QTSHEL, QDCOS, TDCOS, TRFPRD, SLST, SLCCT, LSTSTR, LCTMOM.
STRESS (sub)..........	STRSC, SHL.
PLOTS (sub)...........	PLOTIT.

The main driver, CANOPY/V2, computes local stiffness matrices for beam elements and performs the static condensation required for internal hinge and plastic hinge insertion.

For a structure without plate elements, the subroutines pertaining to plates are bypassed by not calling TPLATE and STRESS from CANOPY/V2. If only plate elements are present, then the majority of the coding in CANOPY/V2 is bypassed, since the local [k]'s are formed by TPLATE, the equations are assembled and solved by SOLVE, and the plate stresses are computed by STRESS.

Buckling analysis is done in routine BUCKLE, called from CANOPY/V2 once for one or more buckling elements.

Subroutines

The 27 subroutines that, along with the driver CANOPY/V2, comprise the PLASTIC CANOPY program are listed here, along with a brief description of what each subroutine does:

1. PROP--computes section properties of beam members.

2. BEAM--assigns parameters for CALBAN; called once for each beam element.

3. BOUND--assigns parameters for CALBAN; called once for each boundary element.

4. CALBAN--calculates bandwidth of each element, saves largest for structure bandwidth, stores element stiffness matrices on auxiliary storage units.

Subroutines 5-9 are used to assemble and solve the global equilibrium equations.

5. ADDSTF--forms global equations in blocks.

6. INL--forms right-hand side of global equations in blocks.

7. USOL--solves equilibrium equations.

8. PRINTD--arranges displacement vector into array DJ so it can be used by CANOPY/V2.

9. SOLVE--acts as a driver for the equation solution procedure.

Subroutines 10-24 are used to formulate plate element stiffness matrices and to compute plate element stresses.

10. TPLATE--reads plate input data, forms load vector, calls other plate subroutines.

11. STRESS--supervises calculation of plate element stresses.

12. SHL--combines bending and membrane stresses, prints stresses.

13. STRSC--computes plate element stresses.

14. QTSHEL--forms stiffness matrix and load vector for plate element, evaluates stresses and moments.

15. STRETR--forms global forces due to normal pressure.

16. CSTSTR--stress displacement transformation for constant strain triangle.

17. LCT9ST--moment resultant-displacement transformation for a three node, linear, curvature compatible, triangular bending element.

18. QDCOS--direction cosine matrix of local element system.

19. TDCOS--direction cosine matrix of local system and projected dimensions of a triangular component.

20. TRFPRD--transformation relating local subtriangle to nodal displacements at the nodes.

21. SLST--forms stiffness matrix for a constant strain triangle (membrane contribution).

22. LSTSTR--computes inplane stresses in a constant strain triangle.

23. SLCCT--forms plate bending stiffness and load vector for a linear, curvature compatible, triangle, with 9 degrees of freedom.

24. LCTMOM--computes moments in a linear, curvature compatible, triangle.

25. BUCKLE--performs all calculations necessary on a buckling element.

26. PLOTS--sets up required input for plot generation routine.

27. PLOTIT--generates graphic file for plot.

Auxiliary Storage Units

During a program execution, groups of data are generated and then stored on temporary, low-speed storage units to be accessed when needed later in the program. The units used in the program and the type of data stored on each are given in table 3.

TABLE 3. - Auxiliary storage units

Logical unit	Stored information
2................	Deflection array after solution of structure equations.
3................	Load vector, written in blocks.
4................	Assembled stiffness matrix and load matrix in blocked form.
7................	Spare unit used in ADDSTF to assist equation assembly process.
8................	All local element stiffness matrices, in the order beams, plates, boundary.
10................	Local stiffness arrays for all plate elements.
11................	Local stiffness arrays for plates (formatted differently than on 10).
14................	Principal stresses, plate elements.
15................	Beam member end reactions.
16................	Do.
17................	Do.
18................	Local stiffness matrix for all beam elements.

In table 4, each auxiliary unit is listed along with the subroutines from which it is accessed by nonformatted READ and WRITE statements.

TABLE 4. - Auxiliary storage access

Unit	Read	Write
2......................	PRINTD STRESS	USOL CANOPY /V2
3......................	ADDSTF	INL
4......................	USOL	ADDSTF
7......................	ADDSTF	ADDSTF
8......................	ADDSTF	CALBAN CANOPY/V2
10......................	STRESS STRSC	TPLATE
11......................	CANOPY/V2	CALBAN
14......................	SHL	SHL
15......................	CANOPY/V2	CANOPY/V2
16......................	CANOPY/V2	CANOPY/V2
17......................	CANOPY/V2	CANOPY/V2
18......................	CANOPY/V2	CANOPY/V2

The current version of the program has the following size limitations:

Number of joints:..................................	100
Number of beams:...................................	100
Number of plates:..................................	150
Number of internal hinges:.........................	10
Number of plastic load steps:......................	20
Number of beam element geometries:.................	20
Number of buckling members:........................	5
Number of joints with restraints:..................	20

These limits can be increased by enlarging the appropriate DIMENSION statements.

INPUT INSTRUCTIONS

Input Card Sequence

Sequence	Information	Number
1...........	Title....................................	1
2a..........	First control card; program options......	1
2b..........	Second control card; structure definition	1
3...........	Joint designation cards..................	NNC
4...........	Geometric properties, beam elements (omit if NMPT = 0)......................	NMPT
4a(optional)	Properties for beam type 6..............	2
5...........	Beam member designation cards (omit if NMC = 0).......................	NMC
5a(optional)	Beam orientation, if AA = 1.............	1
6...........	Plate element designation cards (omit if NUMPL = 0).....................	NUMPL, or less.
7...........	Joint restraint cards....................	NRJ
8...........	Load data control........................	1
9...........	Loaded joint cards (omit if NLJC = 0)....	NLJC
10...........	Loaded member cards (omit if NLMC = 0)...	NLMC
11(optional).	Beam buckling element designation cards (omit if NBM = 0).......................	NBM
12(optional).	Plot orientation.........................	NVIEW

The variable names appearing in the last column are read from card 2b, structure definition card.

For multiple loadings on a structure, repeat card 2a and cards 8 through 12 for each additional loading.

For multiple structures in a single run, repeat the entire card sequence for each structure.

Input Format

1. Title card — Program title

2a. Control card 1 — Program options
Format (I5, F10.4, 7I5, F10.2, 2I5)

Column	Variable	Description
5	IPLAS	1 = plastic analysis 0 = elastic analysis
6-15	DLIMIT	Deflection limitation, inches, for plastic runs
16-20	JOINT	Node point of DLIMIT deflection limitation
25	IDIREC	Direction of deflection limitation, DLIMIT 1 = global X-direction 2 = global Y-direction 3 = global Z-direction
30	IPLOTI	1 = plot input geometry 0 = do not plot input geometry
36-40	NVIEW	Number of plot orientations
45	ISHIFT	1 = advance plot frame 0 = do not advance plot frame Use ISHIFT = 0 to superimpose deflected and undeflected plots.
50	IANGLE	Plot orientation flag: 1 = input plot orientation angles on card(s) 12 0 = use standard plot orientation
51-60	DMAG	Magnification factor, deformed plot
65	IPR	1 = print results after each load step 0 = print results after last load step (applies only to plastic runs).
70	NBM	Number of buckling members

2b. Control card 2 Structure definition
Format (9I5, 3F10.0, F5.3)

Column	Variable	Description
1-5	NST	Number of structural geometries (must be 1 for the last of a series of geometries).
6-10	NJ	Number of joints (nodes)
11-15	NNC	Number of joint designation cards
16-20	NMTP	Number of beam cross section geometries
21-25	M	Number of beam elements
26-30	NMC	Number of beam designation cards
31-35	NUMPL	Number of plate elements
36-40	NRJ	Number of restrained joints
41-45	NLS	Number of loading conditions
46-55	E	Young's modulus, beams
56-65	G	Shear modulus, beams
66-75	EP	Young's modulus, plates
76-80	GP	Poisson's ratio, plates

If EP and GP are blank, the values E and G are used for beam and plate elements.

3. Joint designation cards
Format (2I5, 6F10.2, I5)

Column	Variable	Description
1-5	JP	Joint JP
6-10	J1	Joint J1
11-20	X(JP)	X_s coordinate of JP, inches
21-30	Y(JP)	Y_s coordinate of JP, inches
31-40	Z(JP)	Z_s coordinate of JP, inches
41-50	X(J1)	X_s coordinate of J1, inches
51-60	Y(J1)	Y_s coordinate of J1, inches
61-70	Z(J1)	Z_s coordinate of J1, inches
71-75	JINCR	Joint designation increment number

If JP = J1, designation and coordinates of a single joint are being input and X(JP), Y(JP), and Z(JP) are not required; JINCR is input as 1. When JP $\neq$ J1, coordinates for intermediate joints are calculated by linear interpolation between input values for joints JP and J1. Joint designations are calculated by incrementing JP by JINCR until J1 is reached.

4. Geometric properties, beam elements
Format (2I5, F10.0, 4F10.4)

Column	Variable	Description
1-5	I	Member geometric property number
6-10	TYPE(I)	Type of geometric cross section for member
	TYPE(I) = 1	I-beam
	TYPE(I) = 2	Rectangular or square tubing
	TYPE(I) = 3	Circular tubing or pipe
	TYPE(I) = 4	Rectangular solid
	TYPE(I) = 5	Circular solid
	TYPE(I) = 6	General solid; input section properties on next two cards.
11-20	YSTRSM(I)	Yield strength of member, psi
21-30	H	Height of member; if TYPE(I) = 3 or 5, H is outside diameter.
31-40	B	Width of member; if TYPE(I) = 3 or 5, B is not input.
41-50	TW	If TYPE(I) = 1 or 2, TW is web thickness If TYPE(I) = 3, TW is wall thickness If TYPE(I) = 4 or 5, TW is not input
51-60	TF	If TYPE(I) = 3, 4 or 5, TF is not input

If TYPE(I) = 6, H, B, TW, and TF are not required; instead, two section properties cards are read in right after the current member geometric properties card.

4a. Section property cards (input only if TYPE(I) = 6)

First card
Format (7F10.3)

Column	Variable	Description
1-10	AX	Member cross-sectional area
11-20	IXP	Torsional constant about X_m axis
21-30	IYP	Moment of inertia about Y_m axis
31-40	IZP	Moment of inertia about Z_m axis
41-50	ACXP	Distance from X_m axis to extreme fiber at which highest torsional stress occurs.
51-60	FP	Shape factor for bending shear; can be approximated as 1 if not known.
61-70	BR	Ratio of plastic modulus to elastic modulus

Theoretical values of the ratio BR are given in appendix C for various regular-shaped cross sections. These can be used as a guide for approximating BR for a general shape, or it can be taken as 1.0.

4a. (Continued)

Second card
Format (8F10.3)

Column	Variable	Description
1-10	ACYM(I,1)	Extreme fiber coordinates for bending stress computations.
11-20	ACZM(I,1)	
21-30	ACYM(I,2)	
31-40	ACZM(I,2)	
41-50	ACYM(I,3)	
51-60	ACZM(I,3)	
61-70	ACYM(I,4)	
71-80	ACZM(I,4)	

ACYM and ACZM are the Z_m and Y_m coordinates, respectively, of up to four points on a member's cross section at which the maximum bending stresses could occur. For example, if the member were a rectangular solid, the four points would be the four corners. Figure 19 shows coordinates of point 1.

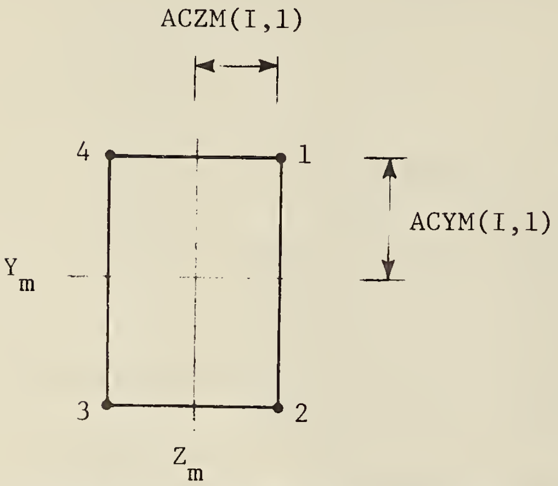


FIGURE 19. - Extreme fiber coordinates.

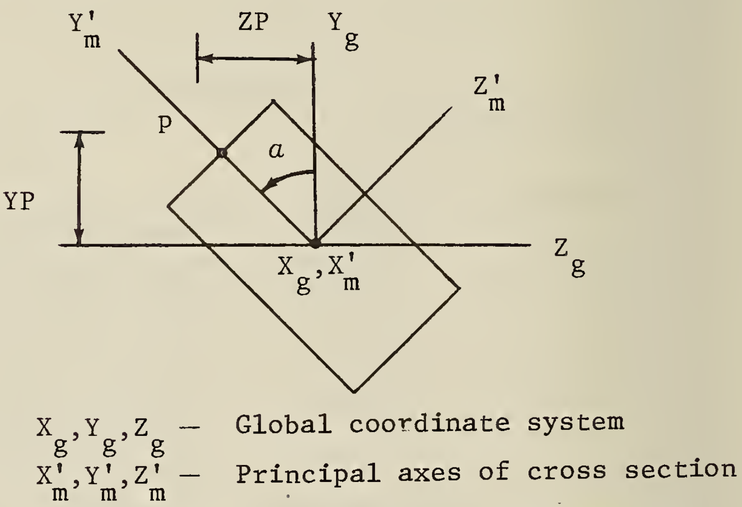

Y'_m
ZP
Y_g
Z'_m
P
a
YP
X_g, X'_m
Z_g
X_g, Y_g, Z_g — Global coordinate system
X'_m, Y'_m, Z'_m — Principal axes of cross section

FIGURE 20. - Beam member rotation coordinates.

5. Member designation cards
Format (13I5)

Column	Variable	Description
1-5	IP	Member number IP
6-10	J1	Member number J1
11-15	JJ(IP)	Node number for end j, member IP
16-20	JK(IP)	Node number for end k, member IP
25	AA	Rotation of member IP is indicated by AA = 0, angle a is zero AA = 1, angle a is not zero
26-30	MTP	Member geometric property number, member IP
31-35	MINCR	Member designation increment number
40	IX1	Internal hinge flag; X_m rotation, joint JJ(IP)
45	IY1	Internal hinge flag; Y_m rotation, joint JJ(IP)
50	IZ1	Internal hinge flag; Z_m rotation, joint JJ(IP)
55	IX2	Internal hinge flag; X_m rotation, joint JJ(IP)
60	IY2	Internal hinge flag; Y_m rotation, joint JJ(IP)
65	IZ2	Internal hinge flag; Z_m rotation, joint JJ(IP)

Internal hinge flag = 1, release corresponding rotation.

Internal hinge flag = 0, do not release rotation.

If IP = J1, designation of a single member is being input; MINCR is not required. When IP ≠ J1, member designations are calculated by incrementing IP by 1 until J1 is reached and by incrementing JJ(IP) and JK(IP) by MINCR until JJ(J1) and JK(J1) are reached. If AA = 1, a member rotation card must be read next. Members with internal hinges must be input one at a time.

5a. Member rotation card (input only if AA = 1)
Format (3F 10.5)

Column	Variable
1-10	XP
11-20	YP
21-30	ZP

XP, YP, and ZP are x, y, and z coordinates, respectively, for a point p, which lies in the principal plane X_m'-Y_m' of members IP to J1 but not on the member axis. The member rotation card is read in after the current member designation card. Figure 20 illustrates how these coordinates are determined.

6. Plate designation cards
Format (6I5, 2F10.0)

Column	Variable	Description
1-5	mm	Plate element number
6-10	I	I - joint for element mm
11-15	J	J - joint for element mm
16-20	K	K - joint for element mm
21-25	L	L - joint for element mm
26-30	INCL	Plate designation increment number
31-40	EL(1)	Element thickness, inches
41-50	EL(2)	Element pressure, psi

Notes on plate input cards:

Plate element numbers must be defined in ascending order beginning with 1 and ending with NUMPL; repeated elements are illegal. Omitted plate element cards are generated; however, the last plate element (NUMPL) must always be input directly.

For omitted element numbers, the program automatically generates omitted information as follows: Let M and N be the element numbers mm read on two successive plate input cards, with M less than N. Element numbers are incremented by 1 until N-1 is reached. Corresponding nodes are incremented by the plate increment number, INCL. Thickness and pressure for the generated elements are the same as for element N.

The program evenly divides the total load due to a pressure to the nodes of a plate element.

For a multiple loading run, the pressure is the same for each load case.

7. Joint restraint cards
Format (7I5)

Column	Variable	Description
1-5	K	Restrained joint K
10	RL(6*K-5)	Restraint index for X_s translation
15	RL(6*K-4)	Restraint index for Y_s translation
20	RL(6*K-3)	Restraint index for Z_s translation
25	RL(6*K-2)	Restraint index for X_s rotation
30	RL(6*K-1)	Restraint index for Y_s rotation
35	RL(6*K)	Restraint index for Z_s rotation

If RL(P) = 1, displacement P is restrained with a boundary element; if RL(P) = 0, displacement P is allowed to occur.

8. Load data card
Format (2I5)

Column	Variable	Description
1-5	NLJC	Number of loaded joint cards
6-10	NLMC	Number of loaded beam member cards

9. Loaded joint cards
Format (3I5, 6F10.0)

Column	Variable	Description
1-5	KI	Loaded joint KI
6-10	KJ	Loaded joint KP
11-15	INCRP	Loaded joint increment number
16-25	AFX	Force in X_s direction, lb
26-35	AFY	Force in Y_s direction, lb
36-45	AFZ	Force in Z_s direction, lb
46-55	AMX	Moment about X_s axix, in-lb
56-65	AMY	Moment about Y_s axis, in-lb
66-75	AMZ	Moment about Z_s axis, in-lb

Joints KI, KI + INCRP, KI + 2*INCRP, ..., KJ are subjected to loads AFX, AFY, AFZ, AMX, AMY, and AMZ. If KI = KJ, a single joint is being loaded and INCRP must be input as 1.

10. Loaded member cards
Format (3I5, 3F10.3)

Column	Variable	Description
1-5	MI	Uniformly loaded member MI
6-10	MJ	Uniformly loaded member MJ
11-15	INCRW	Uniformly loaded member increment number
16-25	WXB	Uniform load in X_s direction, lb/in
26-35	WYB	Uniform load in Y_s direction, lb/in
36-45	WZB	Uniform load in Z_s direction, lb/in

Members MI, MI + INCRW, MI + 2*INCRW, ..., MJ are subjected to uniform loads WXB, WYB, and WZB. If MI = MJ, a single member is being loaded and INCRW must be input as 1.

11. Beam buckling cards
Format (415)

Column	Variable	Description
1-5	NEP1	Nodal number, endpoint 1, buckling member
6-10	NEP2	Nodal number, endpoint 2, buckling member
11-15	NM1	Beam element containing node NEP1
16-20	NM2	Beam element containing node NEP2

A buckling member may consist of one or more beam elements. Figure 21 shows two possible buckling members, and their input cards.

12. Plot orientation
Format (2F 10.4)

Column	Variable	Description
1-10	THETA	Plot orientation angles;
11-20	PHI	See section plot package.

This card is read only if IANGLE = 1 on card 2a; if IANGLE = 0 and plotting options are active, the orientation angles default to THETA = 120°, PHI = 30°.

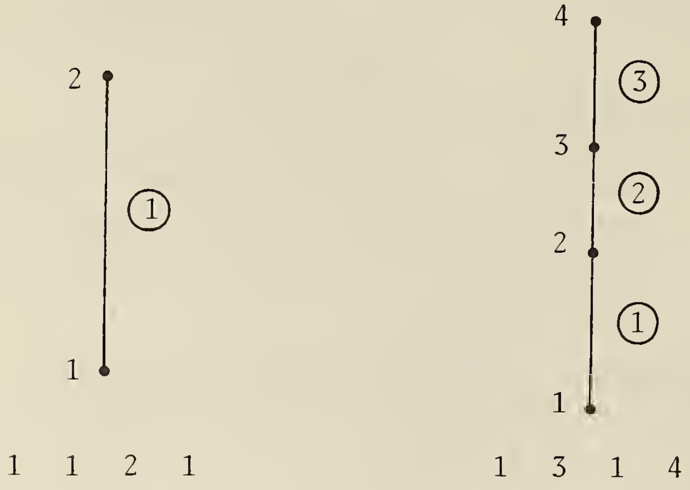


FIGURE 21. - Buckling input cards.

OUTPUT INTERPRETATION

Output generated by PLASTIC CANOPY consists of the following 15 groups of information. They will appear in the order listed; sections that do not apply on a specific run are omitted.

1. Program description parameters, options.

2. Output abbreviation descriptions.

3. Beam element properties

4. Joint restraints

5. Equation parameters
6. Loading data
7. Joint displacements
8. Restrained joint reactions
9. Beam member stresses
10. Beam member end forces
11. Buckling summary
12. Shell element stresses, member axes
13. Shell element stresses, principal axes
14. Loading summary
15. Plastic analysis summary

The 15 groups of data above are described in more detail in the following paragraphs:

1. Program description parameters and options repeat the data input on the two control cards. Program options are printed for each load case; program description parameters are printed once for each structural geometry.

2. A table of abbreviations used in the beam element property table and beam element stress summary table is printed once for each structure geometry. It is omitted on structures with only plate elements.

3. Section properties of all beam elements are summarized; included are the nodal numbers of the beam endpoints, moments of inertia, distances to extreme fibers, cross-sectional area, shear and bending shape factors, and direction cosines. The table is omitted when there are no beam elements; it is printed for each structural geometry in a run. Abbreviations in this table are explained in group 2.

4. Tabulates all joints that have an external restraint; each joint has a 1 or 0 entry for each of the six degrees of freedom, in the global coordinate system. A 1 denotes a restrained degree of freedom; 0 denotes an unrestrained degree of freedom. This table appears once for each structure geometry.

5. Equation parameters listed are total number of equations, maximum bandwidth, equations in a block, and number of blocks. Printed once for each structural geometry.

6. Prints number of loaded joint cards and loaded member cards that were read for this load case; lists loaded nodes and magnitude of the loading, and loaded members and the magnitude. This appears once for each load case; for multiple-load cases, this group of data follows the program options for the second and all subsequent load cases.

7. Displacements of all joints, in global coordinates, are printed for each load case. For a plastic analysis, the displacements are the summation of all the load increments. If the extra print option (IPR = 1) is used in a plastic analysis, the displacements are printed after each load increment (based on the magnitude of loads on the input cards), and finally for the summation of all load increments, based on the actual ultimate load.

8. Prints the reactions, in global coordinates, at all restrained joints; a nonzero reaction will occur for most degrees of freedom that have corresponding input parameters of 1 from section 4. This is printed for each load case. If IPR = 1 on a plastic run, cumulative reactions are printed after each load increment.

9. Tabulates the following stresses at the two endpoints of each beam element: Axial stress (SIGAX), combined bending stress (SIGBMX), torsional shear stress (TAUMAX), combined bending and axial stress (SIGMAX), principal stresses (SIGMA1 and SIGMA2), and von Mises effective stress (VMISES). Also prints the ratio of von Mises stress over material yield stress (VMISES/ALLOW), and a column of integers under HINGE, which indicates members that have had plastic hinges applied. A zero in this column indicates no hinge; an integer denotes a hinge, and its value is the load step in which the hinge was applied.

For an elastic analysis, the highest stressed point in any beam element, based on the von Mises stress, VMISES, should equal the yield stress. VMISES/ALLOW will be 1.0 at this point, and lower for all other points. Bending stresses are computed based on the elastic modulus of the section.

For a plastic analysis, the terms SIGBMX, SIGMAX, SIGMA1, SIGMA2, and VMISES are not allowed to exceed the material yield stress. This is consistent with the assumption of an elastic-perfectly plastic material. Also by definition, a plastic hinge develops when the fully plastic bending moment has been reached; that is, when the whole cross section has yielded rather than just the extreme fiber. Thus bending stress on a yielded section cannot be computed from strength-of-materials formulas using the elastic bending modulus, but must use the plastic bending modulus. A value for any of the above stress terms equal to the material yield stress will indicate that some or all of the cross section has yielded.

As loading progresses in a plastic analysis, axial stress at a hinge (that is, a fully yielded cross section) will continue to increase, exceeding the value computed when the hinge first formed. For most loading configurations, the increase in axial stress is insignificant, around 2 to 3 percent of the yield stress. However, in certain cases, where large axial stresses contribute to, and develop after, hinge formation, the error is larger. When axial stress in a member reaches the yield stress, a warning is printed indicating that this member may not be able to withstand additional axial stress. This warning is unlikely to appear on typical problems, but the results should be examined carefully by the user when it does appear in the output.

10. The end shears, axial throust, bending, and torsional moments at both ends of each beam member are printed, all in the beam element coordinate system. With IPR = 1 on a plastic run, this table is printed after each load increment.

11. Summary of beam buckling analysis; one of the following three output groups is printed for each buckling element.

a. The axial force is tensile or less than 15 percent of the Euler load ($\pi^2 EI/L^2$)--For this case, NO will be printed under the column heading P.GT.15% P CRITICAL.

b. The combined bending and axial forces caused the element to buckle--YES is printed under the column heading P.GT.15% P CRITICAL, and under the column heading MEMBER BUCKLE is printed YES,Z or YES,Y, where Z and Y refer to element coordinate axes of the beam member NM1.

c. The axial force exceeds 15 percent of the Euler load but does not cause buckling--P.GT.15% P CRITICAL column is YES and the MEMBER BUCKLE column is NO. Also the maximum von Mises stress along the buckling element is computed. An additional warning will be printed for any member in which the axial stress or the von Mises stress exceeds the yield stress.

This table occurs after the beam member force table in an elastic run, and after the loading data (item 6) in a plastic run.

12. Prints membrane stresses and bending stresses in each plate element, and superimposes them on the upper and lower surfaces of the plates. The two components are added on the upper surface and subtracted on the lower surface. All stresses are in the local plate element coordinate system, at the centroid of the element.

13. Principal stresses, orientation of the principal axes with respect to local axes, and the von Mises stress are printed for each plate element, at the centroid. A warning is printed after this table if the effective stress exceeds 36 ksi (user can disregard this warning if higher strength plates have been used, but should then check to make sure the higher stress level is not exceeded).

14. The total input loads and the capacity of the structure are printed. For an elastic beam analysis, the capacity is the load at which first yield occurs; for a plastic analysis, it is the ultimate load capacity. For a plate-element-only analysis, the capacity is the same as the input loads. The weight of the structure is also listed.

15. Printed only after a plastic analysis, lists elastic capacity, plastic capacity, and a summary of the load increments in the plastic analysis. Absorbed energy is included in the incremental summary. If a user-defined deflection limitation is imposed at a node to control program termination, the deflection of this node after each load step is printed. When a deflection limitation is not used, this column is all zeroes.

The 15 output groups described above are illustrated in the following 4 example problems.

EXAMPLE PROBLEMS

Four example problems are presented to illustrate the analysis capabilities of the PLASTIC CANOPY program, and to familiarize the user with input preparation and output format.

Example 1.--4-Post ROPS Structure

Figures 22 and 23 show the node numbers and beam element numbers, respectively, for the computer model used in the first example, a four-post ROPS. Only beam elements are present in this example; all are made of 3- by 3- by 0.1875-inch structural tubing, with yield stress σ_y = 68,000 psi. The triangulation built up in each of the four upper corners is used to simulate gusseting in these areas.

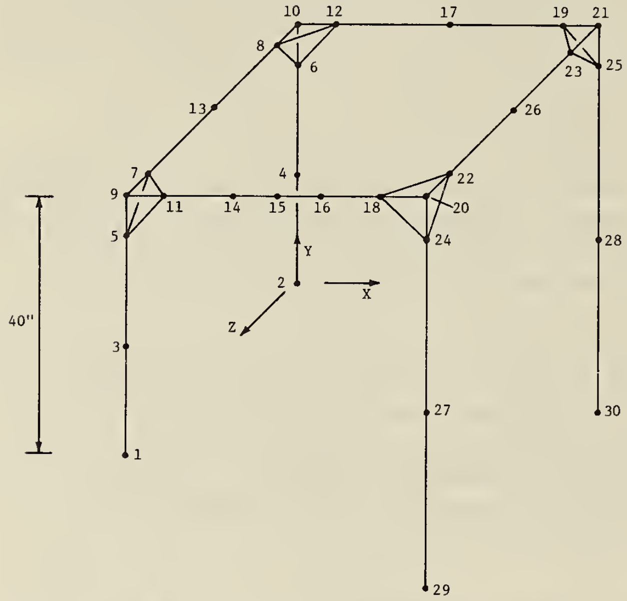


FIGURE 22. - Nodal numbers, example 1.

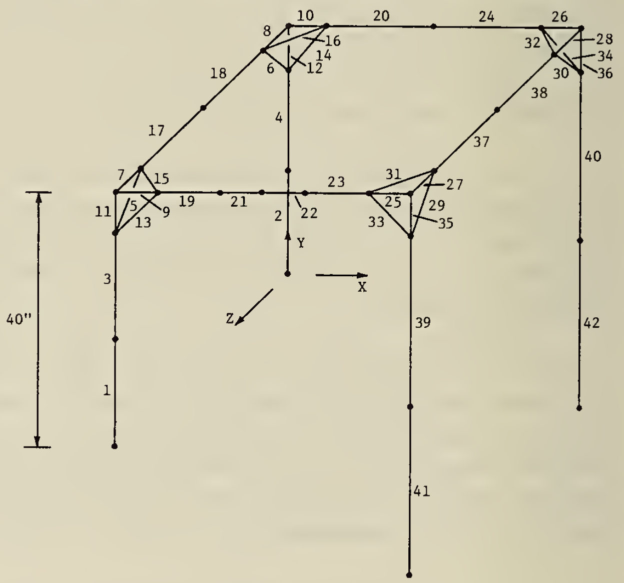


FIGURE 23. - Beam element numbers, example 1.

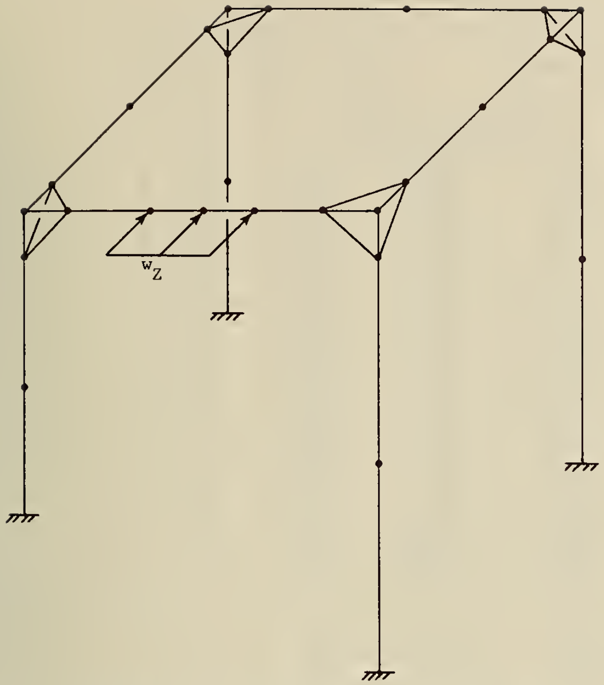


FIGURE 24. - Applied load, example 1.

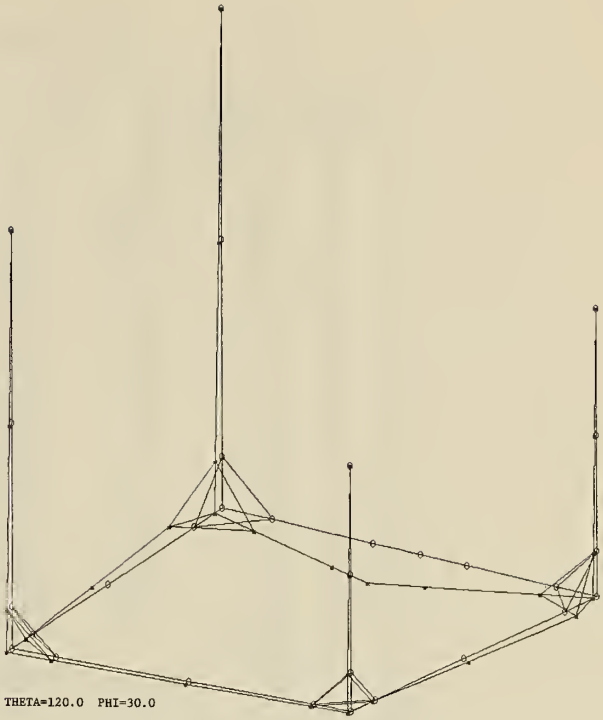


FIGURE 25. - Deformed and undeformed geometry plot, example 1.

Two loading cases are solved; the applied loads, shown in figure 24, are identical in each case, but the analysis in the first load case is plastic, with a deflection limitation of 10 inches at node 15, while the second case uses the elastic mode. For the first load case, deformed and undeformed geometries are plotted and are shown in figure 25.

Table 5 shows the input data, and table 6 the printed output.

TABLE 5. - Input cards for example structure 1

```
     EXAMPLE STRUCTURE 1    PLASTIC CANOPY PROGRAM        MARCH 15,1978
    1   10.0      15    3    1    1    1
    1   30   15    1   42   19    0    4    2 28500000. 11090000.
    1    2    0.0      20.0      50.0       0.0      20.0       0.0       1
    3    4    0.0      36.125    50.0       0.0      36.125     0.0       1
    5    6    0.0      50.75     50.0       0.0      50.75      0.0       1
    7    8    0.0      56.5      44.25      0.0      56.5       5.75      1
    9   10    0.0      56.5      50.0       0.0      56.5       0.0       1
   11   12    5.75     56.5      50.0       5.75     56.5       0.0       1
   13   14    0.0      56.5      25.0      18.0      56.5      50.0       1
   15   16   24.0      56.5      50.0      30.0      56.5      50.0       1
   17   18   24.0      56.5       0.0      42.25     56.5      50.0       1
   19   20   42.25     56.5       0.0      48.0      56.5      50.0       1
   21   22   48.0      56.5       0.0      48.0      56.5      44.25      1
   23   24   48.0      56.5       5.75     48.0      50.75     50.0       1
   25   26   48.0      50.75      0.0      48.0      56.5      25.0       1
   27   28   48.0      26.125    50.0      48.0      26.125     0.0       1
   29   30   48.0       0.0      50.0      48.0       0.0       0.0       1
    1    6   68000.
  2.01      4.17      2.616     2.616     1.41      1.87      1.27
   1.5       1.5       1.5      -1.5      -1.5       1.5      -1.5      -1.5
    1    4    1    3    0    1    1
    5   10    5    7    0    1    1
   11   12    5    9    0    1    1
   13   14    5   11    0    1    1
   15   16    7   11    0    1    1
   17   17    7   13    0    1    1
   18   18    8   13    0    1    1
   19   19   11   14    0    1    1
   20   20   12   17    0    1    1
   21   22   14   15    0    1    1
   23   24   16   18    0    1    1
   25   30   18   20    0    1    1
   31   32   18   22    0    1    1
   33   34   18   24    0    1    1
   35   36   20   24    0    1    1
   37   37   22   26    0    1    1
   38   38   23   26    0    1    1
   39   40   24   27    0    1    1
   41   42   27   29    0    1    1
    1    1    1    1    1    1    1
    2    1    1    1    1    1    1
   29    1    1    1    1    1    1
   30    1    1    1    1    1    1
    0    1
   21   22    1    0.0       0.0      -100.0
    0    0.0       0    0
    0    1
   21   22    1    0.0       0.0      -100.0
```

TABLE 6. - Output listing, example structure 1

```
                        - -  P L A S T I C   C A N O P Y   R E S U L T S  - -

EXAMPLE STRUCTURE 1   PLASTIC CANOPY PROGRAM       MARCH 15,1978
                                                 /

 • •  S T R U C T U R E   D A T A

      NUMBER OF JOINTS=  30

      NUMBER OF JT. DESIGNATION CARDS=  15

      NUMBER OF BEAM GEOMETRIES=   1

      NUMBER OF BEAM ELEMENTS=  42

      NUMBER OF BEAM ELEMENT DESIGNATION CARDS=  19

      NUMBER OF PLATE ELEMENTS=   0

      NUMBER OF RESTRAINED JOINTS=   4

      NUMBER OF LOADING CONDITIONS=   2

      NUMBER OF STRUCTURE GEOMETRIES=   4

      YOUNG S MODULUS FOR BEAMS= 28500000.

      SHEAR MODULUS FOR BEAMS= 11090000.

      YOUNG S MODULUS FOR PLATES= 28500000.

      POISSON RATIO FOR PLATES= .28


 • •  P R O G R A M   O P T I O N S

      PLASTIC ANALYSIS:  YES

      PLOT UNDEFORMED GEOMETRY:  YES

      PLOT DEFORMED GEOMETRY:  YES

      NO. OF BUCKLING ELEMENTS:   0
```

TABLE 6. - Output listing, example structure 1--Continued

```
        - - O U T P U T   A B B R E V I A T I O N S


ABBREVIATIONS USEO IN BEAM MEMBER PROPERTIES TABLE

     JJ =NODAL NUMBER OF BEAM ENOPOINT
     JK =NOOAL NUMBER OF BEAM ENDPOINT
     AX =CROSS SECTIONAL AREA
     IX =TORSIONAL MOMENT OF INERTIA
     IY =BENOING MOMENT OF INERTIA,LOCAL Y-AXIS
     IZ =BENOING MOMENT OF INERTIA,LOCAL Z-AXIS
     AA =FLAG DENOTING BEAM ELEMENT ROTATION
     ACX=DISTANCE TO EXTREME FIBER,TORSION
     ACY=OISTANCE TO EXTREME FIBER,M(Z)
     ACZ=OISTANCE TO EXTREME FIBER,M(Y)
     F  =GEOMETRIC FORM FACTOR,SHEAR OEFORMATIONS
     BM =RATIO OF PLASTIC TO ELASTIC BENOING MOOULUS
     YIELD=MATERIAL YIELO STRESS,PSI
     L  =MEMBER LENGTH,INCHES
     CX =OIRECTION COSINE
     CY =DIRECTION COSINE
     CZ =OIRECTION COSINE


ABBREVIATIONS USED IN BEAM MEMBER STRESS TABLE

     SIGBMX=COMBINED BENDING STRESS ABOUT PRINCIPAL AXES
     SIGAX =AXIAL STRESS
     TAUMAX=TORSIONAL SHEAR STRESS
     SIGMAX=BENOING PLUS AXIAL STRESS
     SIGMA1=PRINCIPAL STRESS
     SIGMA2=PRINCIPAL STRESS
     VMISES=VON MISES EFFECTIVE STRESS
     VMISES/ALLOW=RATIO VON MISES TO MATERIAL YIELD STRESS
     HINGE =NON ZERO ENTRY DENOTES PLASTIC HINGE
```

TABLE 6. - Output listing, example structure 1--Continued

```
COORDINATES OF JOINTS
JOINT        X          Y          Z
   1        .00      20.00      50.00
   2        .00      20.00        .00
   3        .00      36.12      50.00
   4        .00      36.12        .00
   5        .00      50.75      50.00
   6        .00      50.75        .00
   7        .00      56.50      44.25
   8        .00      56.50       5.75
   9        .00      56.50      50.00
  10        .00      56.50        .00
  11       5.75      56.50      50.00
  12       5.75      56.50        .00
  13        .00      56.50      25.00
  14      18.00      56.50      50.00
  15      24.00      56.50      50.00
  16      30.00      56.50      50.00
  17      24.00      56.50        .00
  18      42.25      56.50      50.00
  19      42.25      56.50        .00
  20      48.00      56.50      50.00
  21      48.00      56.50        .00
  22      48.00      56.50      44.25
  23      48.00      56.50       5.75
  24      48.00      50.75      50.00
  25      48.00      50.75        .00
  26      48.00      56.50      25.00
  27      48.00      26.12      50.00
  28      48.00      26.12        .00
  29      48.00        .00      50.00
  30      48.00        .00        .00
```

TABLE 6. - Output listing, example structure 1--Continued

```
MEMBER DESIGNATIONS,PROPERTIES,AND ORIENTATIONS
MEMBER JJ   JK   AX    IX    IY    IZ   AA  ACX   ACY   ACZ    F     BM   YIELD     L      CX     CY     CZ
   1    1    3  2.01  4.17  2.62  2.62   0  1.41  1.50  1.50  1.87  1.27  68000.  16.12   .00   1.00    .00
                                                  1.50 -1.50
                                                 -1.50  1.50
                                                 -1.50 -1.50
   2    2    4  2.01  4.17  2.62  2.62   0  1.41  1.50  1.50  1.87  1.27  68000.  16.12   .00   1.00    .00
                                                  1.50 -1.50
                                                 -1.50  1.50
                                                 -1.50 -1.50
   3    3    5  2.01  4.17  2.62  2.62   0  1.41  1.50  1.50  1.87  1.27  68000.  14.62   .00   1.00    .00
                                                  1.50 -1.50
                                                 -1.50  1.50
                                                 -1.50 -1.50
   4    4    6  2.01  4.17  2.62  2.62   0  1.41  1.50  1.50  1.87  1.27  68000.  14.62   .00   1.00    .00
                                                  1.50 -1.50
                                                 -1.50  1.50
                                                 -1.50 -1.50
   5    5    7  2.01  4.17  2.62  2.62   0  1.41  1.50  1.50  1.87  1.27  68000.   8.13   .00    .71   -.71
                                                  1.50 -1.50
                                                 -1.50  1.50
                                                 -1.50 -1.50
   6    6    8  2.01  4.17  2.62  2.62   0  1.41  1.50  1.50  1.87  1.27  68000.   8.13   .00    .71    .71
                                                  1.50 -1.50
                                                 -1.50  1.50
                                                 -1.50 -1.50
   7    7    9  2.01  4.17  2.62  2.62   0  1.41  1.50  1.50  1.87  1.27  68000.   5.75   .00    .00   1.00
                                                  1.50 -1.50
                                                 -1.50  1.50
                                                 -1.50 -1.50
   8    8   10  2.01  4.17  2.62  2.62   0  1.41  1.50  1.50  1.87  1.27  68000.   5.75   .00    .00  -1.00
                                                  1.50 -1.50
                                                 -1.50  1.50
                                                 -1.50 -1.50
   9    9   11  2.01  4.17  2.62  2.62   0  1.41  1.50  1.50  1.87  1.27  68000.   5.75  1.00    .00    .00
                                                  1.50 -1.50
                                                 -1.50  1.50
                                                 -1.50 -1.50
  10   10   12  2.01  4.17  2.62  2.62   0  1.41  1.50  1.50  1.87  1.27  68000.   5.75  1.00    .00    .00
                                                  1.50 -1.50
                                                 -1.50  1.50
                                                 -1.50 -1.50
  11    5    9  2.01  4.17  2.62  2.62   0  1.41  1.50  1.50  1.87  1.27  68000.   5.75   .00   1.00    .00
                                                  1.50 -1.50
                                                 -1.50  1.50
                                                 -1.50 -1.50
  12    6   10  2.01  4.17  2.62  2.62   0  1.41  1.50  1.50  1.87  1.27  68000.   5.75   .00   1.00    .00
                                                  1.50 -1.50
                                                 -1.50  1.50
                                                 -1.50 -1.50
```

TABLE 6. - <u>Output listing, example structure 1</u>--Continued

```
MEMBER DESIGNATIONS,PROPERTIES,AND ORIENTATIONS
MEMBER JJ   JK   AX    IX    IY    IZ    AA  ACX    ACY   ACZ     F     BM   YIELD     L      CX     CY     CZ
  13    5   11  2.01  4.17  2.62  2.62   0  1.41   1.50  1.50  1.87  1.27  68000.   8.13    .71    .71    .00
                                                   1.50 -1.50
                                                  -1.50  1.50
                                                  -1.50 -1.50
  14    6   12  2.01  4.17  2.62  2.62   0  1.41   1.50  1.50  1.87  1.27  68000.   8.13    .71    .71    .00
                                                   1.50 -1.50
                                                  -1.50  1.50
                                                  -1.50 -1.50
  15    7   11  2.01  4.17  2.62  2.62   0  1.41   1.50  1.50  1.87  1.27  68000.   8.13    .71    .00    .71
                                                   1.50 -1.50
                                                  -1.50  1.50
                                                  -1.50 -1.50
  16    8   12  2.01  4.17  2.62  2.62   0  1.41   1.50  1.50  1.87  1.27  68000.   8.13    .71    .00   -.71
                                                   1.50 -1.50
                                                  -1.50  1.50
                                                  -1.50 -1.50
  17    7   13  2.01  4.17  2.62  2.62   0  1.41   1.50  1.50  1.87  1.27  68000.  19.25    .00    .00  -1.00
                                                   1.50 -1.50
                                                  -1.50  1.50
                                                  -1.50 -1.50
  18    8   13  2.01  4.17  2.62  2.62   0  1.41   1.50  1.50  1.87  1.27  68000.  19.25    .00    .00   1.00
                                                   1.50 -1.50
                                                  -1.50  1.50
                                                  -1.50 -1.50
  19   11   14  2.01  4.17  2.62  2.62   0  1.41   1.50  1.50  1.87  1.27  68000.  12.25   1.00    .00    .00
                                                   1.50 -1.50
                                                  -1.50  1.50
                                                  -1.50 -1.50
  20   12   17  2.01  4.17  2.62  2.62   0  1.41   1.50  1.50  1.87  1.27  68000.  18.25   1.00    .00    .00
                                                   1.50 -1.50
                                                  -1.50  1.50
                                                  -1.50 -1.50
  21   14   15  2.01  4.17  2.62  2.62   0  1.41   1.50  1.50  1.87  1.27  68000.   6.00   1.00    .00    .00
                                                   1.50 -1.50
                                                  -1.50  1.50
                                                  -1.50 -1.50
  22   15   16  2.01  4.17  2.62  2.62   0  1.41   1.50  1.50  1.87  1.27  68000.   6.00   1.00    .00    .00
                                                   1.50 -1.50
                                                  -1.50  1.50
                                                  -1.50 -1.50
  23   16   18  2.01  4.17  2.62  2.62   0  1.41   1.50  1.50  1.87  1.27  68000.  12.25   1.00    .00    .00
                                                   1.50 -1.50
                                                  -1.50  1.50
                                                  -1.50 -1.50
  24   17   19  2.01  4.17  2.62  2.62   0  1.41   1.50  1.50  1.87  1.27  68000.  18.25   1.00    .00    .00
                                                   1.50 -1.50
                                                  -1.50  1.50
                                                  -1.50 -1.50
```

TABLE 6. - Output listing, example structure 1--Continued

```
MEMBER DESIGNATIONS,PROPERTIES,AND ORIENTATIONS
MEMBER  JJ   JK   AX    IX    IY    IZ   AA  ACX   ACY   ACZ     F    BM  YIELD     L     CX     CY     CZ
  25    18   20  2.01  4.17  2.62  2.62   0  1.41  1.50  1.50  1.87  1.27  68000.  5.75  1.00    .00    .00
                                                    1.50 -1.50
                                                   -1.50  1.50
                                                   -1.50 -1.50
  26    19   21  2.01  4.17  2.62  2.62   0  1.41  1.50  1.50  1.87  1.27  68000.  5.75  1.00    .00    .00
                                                    1.50 -1.50
                                                   -1.50  1.50
                                                   -1.50 -1.50
  27    20   22  2.01  4.17  2.62  2.62   0  1.41  1.50  1.50  1.87  1.27  68000.  5.75   .00    .00  -1.00
                                                    1.50 -1.50
                                                   -1.50  1.50
                                                   -1.50 -1.50
  28    21   23  2.01  4.17  2.62  2.62   0  1.41  1.50  1.50  1.87  1.27  68000.  5.75   .00    .00   1.00
                                                    1.50 -1.50
                                                   -1.50  1.50
                                                   -1.50 -1.50
  29    22   24  2.01  4.17  2.62  2.62   0  1.41  1.50  1.50  1.87  1.27  68000.  8.13   .00   -.71    .71
                                                    1.50 -1.50
                                                   -1.50  1.50
                                                   -1.50 -1.50
  30    23   25  2.01  4.17  2.62  2.62   0  1.41  1.50  1.50  1.87  1.27  68000.  8.13   .00   -.71   -.71
                                                    1.50 -1.50
                                                   -1.50  1.50
                                                   -1.50 -1.50
  31    18   22  2.01  4.17  2.62  2.62   0  1.41  1.50  1.50  1.87  1.27  68000.  8.13   .71    .00   -.71
                                                    1.50 -1.50
                                                   -1.50  1.50
                                                   -1.50 -1.50
  32    19   23  2.01  4.17  2.62  2.62   0  1.41  1.50  1.50  1.87  1.27  68000.  8.13   .71    .00    .71
                                                    1.50 -1.50
                                                   -1.50  1.50
                                                   -1.50 -1.50
  33    18   24  2.01  4.17  2.62  2.62   0  1.41  1.50  1.50  1.87  1.27  68000.  8.13   .71   -.71    .00
                                                    1.50 -1.50
                                                   -1.50  1.50
                                                   -1.50 -1.50
  34    19   25  2.01  4.17  2.62  2.62   0  1.41  1.50  1.50  1.87  1.27  68000.  8.13   .71   -.71    .00
                                                    1.50 -1.50
                                                   -1.50  1.50
                                                   -1.50 -1.50
  35    20   24  2.01  4.17  2.62  2.62   0  1.41  1.50  1.50  1.87  1.27  68000.  5.75   .00  -1.00    .00
                                                    1.50 -1.50
                                                   -1.50  1.50
                                                   -1.50 -1.50
  36    21   25  2.01  4.17  2.62  2.62   0  1.41  1.50  1.50  1.87  1.27  68000.  5.75   .00  -1.00    .00
                                                    1.50 -1.50
                                                   -1.50  1.50
                                                   -1.50 -1.50
```

TABLE 6. - Output listing, example structure 1--Continued

```
MEMBER DESIGNATIONS,PROPERTIES,AND ORIENTATIONS
MEMBER JJ    JK    AX     IX     IY     IZ     AA   ACX    ACY    ACZ     F       BM    YIELD     L        CX      CY      CZ
  37   22    26   2.01   4.17   2.62   2.62    0   1.41   1.50   1.50   1.87   1.27   68000.   19.25     .00     .00   -1.00
                                                          1.50  -1.50
                                                         -1.50   1.50
                                                         -1.50  -1.50
  38   23    26   2.01   4.17   2.62   2.62    0   1.41   1.50   1.50   1.87   1.27   68000.   19.25     .00     .00    1.00
                                                          1.50  -1.50
                                                         -1.50   1.50
                                                         -1.50  -1.50
  39   24    27   2.01   4.17   2.62   2.62    0   1.41   1.50   1.50   1.87   1.27   68000.   24.62     .00   -1.00     .00
                                                          1.50  -1.50
                                                         -1.50   1.50
                                                         -1.50  -1.50
  40   25    28   2.01   4.17   2.62   2.62    0   1.41   1.50   1.50   1.87   1.27   68000.   24.62     .00   -1.00     .00
                                                          1.50  -1.50
                                                         -1.50   1.50
                                                         -1.50  -1.50
  41   27    29   2.01   4.17   2.62   2.62    0   1.41   1.50   1.50   1.87   1.27   68000.   26.12     .00   -1.00     .00
                                                          1.50  -1.50
                                                         -1.50   1.50
                                                         -1.50  -1.50
  42   28    30   2.01   4.17   2.62   2.62    0   1.41   1.50   1.50   1.87   1.27   68000.   26.12     .00   -1.00     .00
                                                          1.50  -1.50
                                                         -1.50   1.50
                                                         -1.50  -1.50


 JOINT RESTRAINTS
     JOINT  X TRANS.  Y TRANS.  Z TRANS.  X ROTA.  Y ROTA.  Z ROTA.
       1        1         1         1        1        1        1
       2        1         1         1        1        1        1
      29        1         1         1        1        1        1
      30        1         1         1        1        1        1


  E Q U A T I O N   P A R A M E T E R S

   TOTAL NUMBER OF EQUATIONS =  180
   BANDWIDTH                 =   42
   NUMBER OF EQNS IN A BLOCK =   34
   NUMBER OF BLOCKS          =    6
```

TABLE 6. - Output listing, example structure 1--Continued

```
 LOADING NUMBER  1

 NO. OF LOADED JOINT CARDS  =  0
 NO. OF LOADED MEMBER CARDS =  1


DISTRIBUTED LOADS ON MEMBERS
MEMBER      WX         WY         WZ
  21        .00        .00    -100.00
  22        .00        .00    -100.00


JOINT DISPLACEMENTS
JOINT  X TRANS.  Y TRANS.  Z TRANS.   X ROTA.   Y ROTA.   Z ROTA.
   1   .000000   .000000  -.000000  -.013081   .368457   .003876
   2  -.000000  -.000000  -.000000  -.015882   .007521  -.003870
   3  -.007325   .001454  -.296905  -.023513   .377803  -.000877
   4   .006729  -.001456  -.324707  -.024332   .008154   .000970
   5   .010094   .002772  -.631524  -.018228   .386279  -.000823
   6  -.013162  -.002777  -.647223  -.015123   .008728   .001086
   7 -2.210719  -.091440  -.728538  -.015003   .385835  -.000022
   8   .032784   .070522  -.724429  -.010714   .008415   .000292
   9   .015137   .002229  -.728825  -.016557   .387248  -.000716
  10  -.019139  -.002036  -.724713  -.013009   .009106   .000890
  11   .015694  -.002318 -2.958256  -.016252   .388456  -.000577
  12  -.019406   .003377  -.778190  -.012803   .009991   .000726
  13 -1.140837   .039387  -.726484   .007795  -.060334  -.000143
  14   .015328  -.001154 -7.725078  -.014190   .383592   .000594
  15   .015149   .003626-10.000000  -.018404   .015847   .000486
  16   .014969   .004013 -7.942980  -.022618  -.347734   .000099
  17  -.018851   .003107 -1.045541  -.012637   .018318  -.000433
  18   .014603   .005042 -3.598365  -.020556  -.356324  -.000104
  19  -.018296  -.003911 -1.420623  -.012471   .021797  -.000014
  20   .015057   .004121 -1.550067  -.020323  -.355904  -.000246
  21  -.018402  -.003923 -1.546001  -.012484   .021827   .000064
  22  2.061041  -.110410 -1.549457  -.018383  -.354917  -.000706
  23   .106850   .065136 -1.545341  -.009971   .021818   .000434
  24   .014037   .004603 -1.431321  -.022223  -.355267  -.000376
  25  -.018364  -.004596 -1.471469  -.015014   .022029   .000123
  26  1.153316   .016840 -1.547399   .008685   .051809  -.000032
  27  -.005004   .002370  -.654343  -.034272  -.350584  -.000712
  28  -.000467  -.002366  -.751005  -.035830   .017075   .000829
  29   .000000   .000000  -.000000  -.009598  -.345616   .001812
  30  -.000000  -.000000  -.000000  -.014845   .011818  -.001526


REACTIONS AT RESTRAINED JOINTS
JOINT  X FORCE     Y FORCE     Z FORCE    X MOMENT    Y MOMENT    Z MOMENT
  1    -1056.2     -5164.4     6221.6    118875.4    -26802.6     24481.5
  2     1027.8      5172.8     7197.9    121755.8     -1814.1    -24678.3
 29     -300.7     -5196.0     4339.1    130303.8      8794.8     10540.3
 30      329.3      5187.7     5036.0    130548.6     -9304.6    -10522.3
```

TABLE 6. - Output listing, example structure 1--Continued

```
                              MEMBER STRESSES

MEMBER  NODE  SIGBMX    SIGAX    TAUMAX    SIGMAX    SIGMA1    SIGMA2   VMISES  VMISES/ALLOW  HINGE
   1      1   68000.    2569.    -9063.    68000.    68000.    -1195.   68000.      1.00        3
   1      3   15458.    2569.    -9063.    18027.    24047.    -6020.   28377.       .33        0
   2      2  -68000.   -2574.     -613.   -68000.      116.   -68000.   68000.      1.00        2
   2      4  -17278.   -2574.     -613.   -19851.     5153.   -25004.   30144.       .35        0
   3      3   15458.    2569.    -9063.    18027.    24047.    -6020.   28377.       .33        0
   3      5   46410.    2569.    -9063.    48979.    55700.    -6721.   61376.       .71        0
   4      4  -17278.   -2574.     -613.   -19851.     5153.   -25004.   30144.       .35        0
   4      6  -58656.   -2574.     -613.   -61230.     9684.   -68000.   68000.       .93        0
   5      5   25656.    6944.     1693.    32600.    32832.     -232.   32949.       .38        0
   5      7   22644.    6944.     1693.    29588.    29988.     -400.   30212.       .35        0
   6      6  -23757.   -9683.     1505.   -33440.     2130.   -35570.   37630.       .44        0
   6      8  -26683.   -9683.     1505.   -36366.      925.   -37291.   38130.       .44        0
   7      7  -36937.   -1424.     1887.   -38360.      108.   -38468.   38522.       .45        0
   7      9   -8188.   -1424.     1887.    -9612.      380.    -9992.   10188.       .12        0
   8      8   36216.    1407.     1627.    37622.    38037.     -415.   38400.       .44        0
   8     10    8434.    1407.     1627.     9840.    10522.     -682.   11056.       .13        0
   9      9    8239.    2764.     -830.    11003.    11269.     -267.   11444.       .13        0
   9     11   19806.    2764.     -830.    22570.    22860.     -290.   23095.       .27        0
  10     10   -4195.   -1323.     -560.    -5518.      886.    -6404.    6973.       .08        0
  10     12  -17268.   -1323.     -560.   -18591.      427.   -19018.   19254.       .22        0
  11      5  -16134.   -2694.    -2634.   -18828.     3582.   -22411.   25805.       .30        0
  11      9   -7550.   -2694.    -2634.   -10244.     1718.   -11962.   13370.       .15        0
  12      6   26223.    3669.    -1028.    29892.    32941.    -3049.   35974.       .42        0
  12     10    9849.    3669.    -1028.    13518.    15012.    -1494.   16470.       .19        0
  13      5    -255.    1265.    -5646.     1010.     8203.    -7193.   14012.       .16        0
  13     11    6067.    1265.    -5646.     7331.    13647.    -6315.   18990.       .22        0
  14      6    -664.    -222.    -4873.     -885.     9943.   -10828.   19906.       .23        0
  14     12     208.    -222.    -4873.      -13.     9862.    -9876.   18730.       .22        0
  15      7  -23481.   -8188.     2453.   -31669.      508.   -32178.   32547.       .38        0
  15     11  -15199.   -8188.     2453.   -23387.      844.   -24231.   24921.       .29        0
  16      8   18835.    3893.     3431.    22728.    24034.    -1306.   24947.       .29        0
  16     12    8047.    3893.     3431.    11940.    15847.    -3907.   19282.       .22        0
  17      7  -68000.   -3042.      964.   -68000.       11.   -68000.   68000.      1.00        1
  17     13  -27349.   -3042.      964.   -30390.       58.   -30448.   30477.       .35        0
  18      8  -68000.   -3042.      964.   -68000.       16.   -68000.   68000.      1.00        6
  18     13  -27348.   -3042.      964.   -30390.       58.   -30448.   30477.       .35        0
  19     11  -48358.    -852.    -2631.   -49210.     1198.   -50408.   51129.       .59        0
  19     14  -65704.    -852.    -2631.   -66556.      436.   -66992.   67222.       .78        0
  20     12   38306.     866.     -142.    39172.    42482.    -3309.   44653.       .52        0
  20     17   16207.     866.     -142.    17073.    20478.    -3405.   22700.       .26        0
  21     14  -65704.    -852.    -2631.   -66556.      436.   -66992.   67222.       .78        0
  21     15  -68000.    -852.    -2631.   -68000.      391.   -68000.   68000.      1.00        8
  22     15  -68000.    -852.    -2631.   -68000.      391.   -68000.   68000.      1.00        8
  22     16  -68000.    -852.    -2631.   -68000.      471.   -68000.   68000.       .81        0
  23     16  -68000.    -852.    -2631.   -68000.      471.   -68000.   68000.       .81        0
  23     18  -18915.    -852.    -2631.   -19767.     1177.   -20945.   21648.       .25        0
  24     17   16206.     866.     -142.    17073.    20478.    -3405.   22700.       .26        0
  24     19   19781.     866.     -142.    20647.    23399.    -2752.   25175.       .29        0
  25     18    3234.    2251.     -634.     5485.     7590.    -2105.    9627.       .11        0
  25     20    5828.    2251.     -634.     8079.     8854.     -776.    9542.       .11        0
```

TABLE 6. - Output listing, example structure 1--Continued

```
                                   MEMBER STRESSES

MEMBER  NODE  SIGBMX     SIGAX    TAUMAX    SIGMAX    SIGMA1    SIGMA2    VMISES  VMISES/ALLOW  HINGE
  26     19   -8264.     -521.      36.     -8785.    1112.    -9897.    10862.       .13        0
  26     21   -2182.     -521.      36.     -2703.     978.    -3682.     4375.       .05        0
  27     20   -8407.    -3020.   -1251.    -11427.     280.   -11706.    11912.       .14        0
  27     22  -35351.    -3020.   -1251.    -38370.     142.   -38512.    38631.       .45        0
  28     21    8626.     3270.   -1005.     11896.   12597.     -702.    13233.       .15        0
  28     23   26468.     3270.   -1005.     29738.   33940.    -4203.    38127.       .44        0
  29     22   23942.     7739.    -926.     31681.   31833.     -152.    31919.       .37        0
  29     24   24408.     7739.    -926.     32147.   32221.      -74.    32258.       .37        0
  30     23  -30783.   -10260.    -135.    -41043.      88.   -41131.    41176.       .48        0
  30     25  -29674.   -10260.    -135.    -39935.      72.   -40006.    40043.       .46        0
  31     18   -5598.    -6121.   -3774.    -11719.    1488.   -13207.    14034.       .16        0
  31     22  -23075.    -6121.   -3774.    -29195.     602.   -29797.    30108.       .35        0
  32     19    3157.     1061.   -4008.      4218.   10141.    -5924.    15235.       .18        0
  32     23   -3252.     1061.   -4008.     -2191.    9649.   -11840.    20987.       .24        0
  33     18    2327.     -314.    3703.      2013.    6422.    -4410.     9916.       .11        0
  33     24   -5219.     -314.    3703.     -5534.    5543.   -11076.    16066.       .19        0
  34     19    1040.     1531.    3774.      2571.    7369.    -4799.    11539.       .13        0
  34     25   13060.     1531.    3774.     14591.   18933.    -4342.    22881.       .26        0
  35     20   -6377.    -2389.    1731.     -8766.     699.    -9465.     9984.       .12        0
  35     24  -27632.    -2389.    1731.    -30021.     541.   -30562.    31028.       .36        0
  36     21    9302.     3335.     550.     12637.   12687.      -50.    12713.       .15        0
  36     25   33532.     3335.     550.     36867.   36884.      -17.    36893.       .43        0
  37     22  -68000.    -3047.     379.    -68000.       3.   -68000.    68000.      1.00        4
  37     26  -31708.    -3047.     379.    -34755.      11.   -34766.    34772.       .40        0
  38     23  -68000.    -3047.     379.    -68000.       4.   -68000.    68000.      1.00        9
  38     26  -31708.    -3047.     379.    -34755.      11.   -34766.    34771.       .40        0
  39     24   62791.     2585.    2974.     65376.   65877.     -500.    66178.       .77        0
  39     27   11954.     2585.    2974.     14539.   15265.     -726.    15646.       .18        0
  40     25  -68000.    -2581.   -3146.    -68000.     186.   -68000.    68000.       .98       10
  40     28  -16657.    -2581.   -3146.    -19238.    1186.   -20424.    21076.       .24        0
  41     27   11953.     2585.    2974.     14539.   15265.     -726.    15646.       .18        0
  41     29   68000.     2585.    2974.     68000.   68000.     -141.    68000.      1.00        7
  42     28  -16657.    -2581.   -3146.    -19238.    1186.   -20424.    21076.       .24        0
  42     30  -68000.    -2581.   -3146.    -68000.     146.   -68000.    68000.      1.00        5
```

TABLE 6. - Output listing, example structure 1--Continued

```
MEMBER END REACTIONS-MEMBER COORDINATE SYSTEM (J LESS THAN K)
                                       J NODE                                                                    K NODE
MEMBER   X FORCE   Y FORCE   Z FORCE   X MOMENT   Y MOMENT   Z MOMENT      X FORCE   Y FORCE   Z FORCE   X MOMENT   Y MOMENT   Z MOMENT
   1     -5164.4    1056.2    6221.6   -26802.6  -118875.4    24481.5       5164.4   -1056.2   -6221.6    26802.6    18551.3    -7450.0
   2      5172.8   -1027.8    7197.9    -1814.1  -121755.8   -24678.3      -5172.8    1027.8   -7197.9     1814.1     5689.4     8104.7
   3     -5164.4    1056.2    6221.6   -26802.6   -18551.3     7450.0       5164.4   -1056.2   -6221.6    26802.6   -72440.3     7997.2
   4      5172.8   -1027.8    7197.9    -1814.1    -5689.4    -8104.7      -5172.8    1027.8   -7197.9     1814.1   -99580.1    -6927.2
   5    -13957.3      82.6    2660.2     5006.2   -13132.8   -29233.4      13957.3     -82.6   -2660.2    -5006.2    -8498.9    29904.9
   6     19463.3   -1070.4     485.0     4451.4    -5093.8    36076.8     -19463.3    1070.4    -485.0    -4451.4     1149.9   -44780.8
   7      2861.9   -4222.2    4665.6     5581.3   -31728.8   -32292.2      -2861.9    4222.2   -4665.6    -5581.3     4901.4     8014.8
   8     -2827.1    6269.3    2232.9     4812.8   -15377.3    47782.7       2827.1   -6269.3   -2232.9    -4812.8     2538.0   -11734.2
   9     -5555.8    1193.4   -1031.5    -2454.9   -12693.9     1632.3       5555.8   -1193.4    1031.5     2454.9    18624.9     5229.9
  10      2658.8   -1106.3   -2050.9    -1657.5    -5579.1    -1049.2      -2658.8    1106.3    2050.9     1657.5    17371.9    -5312.2
  11      5415.6     890.2   -3893.5    -7791.4    32857.4     1169.4      -5415.6    -890.2    3893.5     7791.4   -10469.7     3949.0
  12     -7375.6    -425.9   -4878.2    -3041.2    41441.5     1314.7       7375.6     425.9    4878.2     3041.2   -13391.6    -3763.6
  13     -2542.3    1454.6     187.5   -16698.4    -2061.9     3659.7       2542.3   -1454.6    -187.5    16698.4      537.4     8169.1
  14       445.2   -1091.9   -2443.3   -14411.2    16789.0    -1136.9       -445.2    1091.9    2443.3    14411.2     3078.9    -7742.3
  15     16458.4    -769.1    2181.7     7255.7   -32893.9    -7625.5     -16458.4     769.1   -2181.7    -7255.7    15153.2     1371.1
  16     -7824.8    1916.8      65.5    10145.8   -14714.6    18522.8       7824.8   -1916.8     -65.5   -10145.8    14182.2    -2935.9
  17      6114.2   -4819.6   -2768.8     2850.1    74170.5   -72719.7      -6114.2    4819.6    2768.8    -2850.1   -20871.8   -20057.8
  18      6113.8    4819.6   -2768.7     2850.1    32426.4   112835.3      -6113.8   -4819.6    2768.7    -2850.1    20872.0   -20057.7
  19      1712.7    -344.8   12337.3    -7782.4   -45967.9    -9237.8      -1712.7     344.8  -12337.3     7782.4  -105164.1     5014.2
  20     -1740.9     353.2    1085.2     -420.4   -43921.3     7956.2       1740.9    -353.2   -1085.2      420.4    24115.8    -1510.5
  21      1712.7    -344.8   12337.6    -7782.4   105164.8    -5014.2      -1712.7     344.8    -935.3     7782.4  -144983.4     2945.4
  22      1712.7    -344.8     935.7    -7782.3   144983.5    -2945.4      -1712.7     344.8   10466.6     7782.3  -116390.7      876.7
  23      1712.7    -344.8  -10466.5    -7782.3   116391.4     -876.7      -1712.7     344.8   10466.5     7782.3    11823.8    -3347.0
  24     -1740.9     353.2    1085.3     -420.4   -24115.7     1510.5       1740.9    -353.2   -1085.3      420.4     4309.7     4935.2
  25     -4523.5    -125.1    -923.8    -1874.6    -2790.4     1481.5       4523.5     125.1     923.8     1874.6     8102.6    -2200.6
  26      1047.2     226.2     -59.5      107.4     -220.6     -362.3      -1047.2    -226.2      59.5     -107.4      563.1     1663.2
  27      6069.3    4677.3   -3416.3    -3701.0    -2981.0   -11711.1      -6069.3   -4677.3    3416.3     3701.0    22624.9    38605.6
  28     -6571.7   -6477.1    -326.7    -2973.1     1064.0    13967.9       6571.7    6477.1     326.7     2973.1      814.6   -51211.5
  29    -15555.2     185.4   -1645.8    -2739.0     6823.8   -34453.4      15555.2    -185.4    1645.8     2739.0     6559.5    35961.1
  30     20622.8     -31.8     588.2     -398.1    -5781.3    46107.4     -20622.8      31.8    -588.2      398.1      998.9   -46365.7
  31     12302.4     911.9   -3146.7   -11161.3     -110.4    -6478.9     -12302.4    -911.9    3146.7    11161.3    25698.2    13893.9
  32     -2132.6   -2586.6    -506.2   -11854.3     1869.3     2788.5       2132.6    2586.6     506.2    11854.3     2247.1   -23822.1
  33       631.9    -968.4    1382.2    10951.5    -1665.9    -1445.5       -631.9     968.4   -1382.2   -10951.5    -9574.3    -6429.4
  34     -3077.0     760.5    3011.1    11160.9     2735.5     1837.5       3077.0    -760.5   -3011.1   -11160.9   -27221.1     4346.7
  35      4802.4   -1107.3    5146.3     5120.4     9836.5    -1500.5      -4802.4    1107.3   -5146.3    -5120.4   -39428.0    -4866.6
  36     -6703.4     720.5    6512.4     1627.2    14075.3     1309.9       6703.4    -720.5   -6512.4    -1627.2   -51522.0     2832.9
  37      6124.6   -5540.8    1411.4     1119.9   -55083.9   -90775.7      -6124.6    5540.8   -1411.4    -1119.9    27914.1   -15885.3
  38      6124.2    5540.8    1411.4     1119.9      744.8   122546.2      -6124.2   -5540.8   -1411.4    -1119.9   -27914.3   -15885.3
  39     -5196.0     300.7   -4339.1     8794.8    89904.1     4720.7       5196.0    -300.7    4339.1    -8794.8    16945.7     2684.3
  40      5187.7    -329.4   -5036.0    -9304.6   125028.8    -6192.2      -5187.7     329.4    5036.0     9304.6    -1017.0    -1918.1
  41     -5196.0     300.7   -4339.1     8794.8   -16945.6    -2684.3       5196.0    -300.7    4339.1    -8794.8   130303.8    10540.3
  42      5187.7    -329.3   -5036.0    -9304.6     1017.1     1918.1      -5187.7     329.3    5036.0     9304.6   130548.6   -10522.3
```

TABLE 6. - Output listing, example structure 1--Continued

```
 INPUT LOADS,GLOBAL COORDINATE SYSTEM

    X DIRECTION:       0. POUNDS
    Y DIRECTION:       0. POUNDS
    Z DIRECTION:   -1200. POUNDS


MAXIMUM LOAD THAT CANOPY CAN SUPPORT IN X DIRECTION IS       0.  POUNDS
MAXIMUM LOAD THAT CANOPY CAN SUPPORT IN Y DIRECTION IS       0.  POUNDS
MAXIMUM LOAD THAT CANOPY CAN SUPPORT IN Z DIRECTION IS   22795.  POUNDS

 WEIGHT OF BEAM ELEMENTS   = 273. POUNDS
 WEIGHT OF PLATE ELEMENTS  =   0. POUNDS
 TOTAL CANOPY WEIGHT       = 273. POUNDS


         * * *   P L A S T I C   A N A L Y S I S   S U M M A R Y



  APPLIED LOADS AT ELASTIC LIMIT: F(X)=       0.
                                  F(Y)=       0.
                                  F(Z)=  -16823.

  APPLIED LOADS AT ULTIMATE:      F(X)=      -0.
                                  F(Y)=      -0.
                                  F(Z)=  -22795.


              LOADING SUMMARY

  LOAD          APPLIED LOADS (LBS)          DEFLECTION,INCHES,NODE IS     ENERGY (IN-LB)
INCREMENT   F(X)        F(Y)       F(Z)       GLOBAL Z DIRECTION
    1        0.          0.      -16823.            -.7237                    5984.
    2        0.          0.      -19532.            -.8832                    8839.
    3        0.          0.      -19747.            -.8989                    9142.
    4        0.          0.      -21139.           -1.0371                   11941.
    5        0.          0.      -22062.           -1.1648                   14674.
    6        0.          0.      -22268.           -1.2045                   15550.
    7        0.          0.      -22347.           -1.2353                   16234.
    8        0.          0.      -22737.           -1.4798                   21735.
    9        0.          0.      -22804.           -4.5055                   79775.
   10        0.          0.      -22805.          -10.0000                  185594.
```

TABLE 6. - Output listing, example structure 1--Continued

```
  • •  P R O G R A M   O P T I O N S

       PLASTIC ANALYSIS:   NO

       PLOT UNDEFORMED GEOMETRY:   NO

       PLOT DEFORMED GEOMETRY:   NO

       NO. OF BUCKLING ELEMENTS:   0


  LOADING NUMBER  2

  NO. OF LOADED JOINT CARDS   =  0
  NO. OF LOADED MEMBER CARDS  =  1

 DISTRIBUTED LOADS ON MEMBERS
 MEMBER      WX        WY        WZ
   21        .00       .00    -100.00
   22        .00       .00    -100.00


 REACTIONS AT RESTRAINEO JOINTS
 JOINT  X FORCE     Y FORCE     Z FORCE     X MOMENT     Y MOMENT     Z MOMENT
    1     -997.6     -3502.4      4248.6     80283.3     -16165.8      19140.4
    2      993.8      3501.6      4234.5     79812.3       -986.2     -19209.7
   29     -379.4     -2124.5      2380.9     68638.3       3147.8      10191.2
   30      383.3      2125.4      2379.0     68485.2      -6455.1     -10240.1
```

TABLE 6. - Output listing, example structure 1--Continued

```
                                   MEMBER STRESSES

MEMBER  NODE  SIGBMX     SIGAX     TAUMAX     SIGMAX     SIGMA1     SIGMA2      VMISES   VMISES/ALLOW   HINGE
    1     1    57009.     1742.    -5466.     58751.     59256.      -504.      59509.        .88          0
    1     3     8503.     1742.    -5466.     10246.     12614.     -2369.      13950.        .21          0
    2     2   -56779.    -1742.     -333.    -58521.         2.    -58523.      58524.        .86          0
    2     4    -8438.    -1742.     -333.    -10180.        11.    -10191.      10197.        .15          0
    3     3     8503.     1742.    -5466.     10246.     12614.     -2369.      13950.        .21          0
    3     5    35490.     1742.    -5466.     37233.     38019.      -786.      38418.        .56          0
    4     4    -8438.    -1742.     -333.    -10180.        11.    -10191.      10197.        .15          0
    4     6   -35406.    -1742.     -333.    -37148.         3.    -37151.      37152.        .55          0
    5     5    16499.     4974.     1695.     21472.     21605.      -133.      21672.        .32          0
    5     7    17472.     4974.     1695.     22445.     22572.      -127.      22636.        .33          0
    6     6   -12455.    -5215.     1195.    -17671.        80.    -17751.      17792.        .26          0
    6     8   -13625.    -5215.     1195.    -18840.        75.    -18916.      18954.        .28          0
    7     7   -28795.     -640.     1400.    -29435.        66.    -29502.      29535.        .43          0
    7     9    -5903.     -640.     1400.     -6543.       287.     -6830.       6978.        .10          0
    8     8    19354.      481.      916.     19836.     19878.       -42.      19899.        .29          0
    8    10     4609.      481.      916.      5090.      5250.      -160.       5332.        .08          0
    9     9     5584.     1947.     -409.      7531.      7554.       -22.       7565.        .11          0
    9    11    13150.     1947.     -409.     15097.     15108.       -11.      15114.        .22          0
   10    10    -2063.     -551.     -431.     -2614.        69.     -2683.       2718.        .04          0
   10    12    -9913.     -551.     -431.    -10464.        18.    -10482.      10491.        .15          0
   11     5   -13962.    -2215.    -1641.    -16177.       165.    -16342.      16425.        .24          0
   11     9    -6169.    -2215.    -1641.     -8384.       310.     -8694.       8852.        .13          0
   12     6    14145.     2089.     -446.     16235.     16247.       -12.      16253.        .24          0
   12    10     5857.     2089.     -446.      7946.      7971.       -25.       7983.        .12          0
   13     5      213.     1379.    -3965.      1592.      4840.     -3248.       7049.        .10          0
   13    11     6840.     1379.    -3965.      8219.      9820.     -1601.      10710.        .16          0
   14     6    -6228.     -812.    -2674.     -7040.       901.     -7941.       8427.        .12          0
   14    12    -5116.     -812.    -2674.     -5928.      1028.     -6956.       7523.        .11          0
   15     7   -18008.    -6025.     1858.    -24033.       143.    -24176.      24247.        .36          0
   15    11   -10025.    -6025.     1858.    -16050.       212.    -16262.      16370.        .24          0
   16     8    10248.     2557.     1506.     12806.     12980.      -175.      13069.        .19          0
   16    12     7135.     2557.     1506.      9692.      9921.      -229.      10037.        .15          0
   17     7   -66320.    -1668.      759.    -67987.         8.    -67996.      68000.       1.00          1
   17    13   -10934.    -1668.      759.    -12602.        46.    -12647.      12670.        .19          0
   18     8   -44451.    -1668.      759.    -46119.        12.    -46131.      46137.        .68          0
   18    13   -10934.    -1668.      759.    -12602.        46.    -12647.      12670.        .19          0
   19    11   -31309.     -520.     -145.    -31830.         1.    -31830.      31831.        .47          0
   19    14   -32118.     -520.     -145.    -32639.         1.    -32639.      32640.        .48          0
   20    12    22777.      522.     -136.     23299.     23300.        -1.      23301.        .34          0
   20    17     8016.      522.     -136.      8538.      8540.        -2.       8541.        .13          0
   21    14   -32118.     -520.     -145.    -32639.         1.    -32639.      32640.        .48          0
   21    15   -45058.     -520.     -145.    -45578.         0.    -45579.      45579.        .67          0
   22    15   -45058.     -520.     -145.    -45578.         0.    -45579.      45579.        .67          0
   22    16   -36152.     -520.     -145.    -36672.         1.    -36673.      36673.        .54          0
   23    16   -36152.     -520.     -145.    -36672.         1.    -36673.      36673.        .54          0
   23    18    -8153.     -520.     -145.     -8673.         2.     -8675.       8677.        .13          0
   24    17     8016.      522.     -136.      8538.      8540.        -2.       8541.        .13          0
   24    19     6746.      522.     -136.      7268.      7270.        -3.       7272.        .11          0
   25    18     2727.     1470.      -94.      4197.      4199.        -2.       4200.        .06          0
   25    20     3662.     1470.      -94.      5132.      5134.        -2.       5135.        .08          0
```

TABLE 6. - Output listing, example structure 1--Continued

```
                              MEMBER.STRESSES

MEMBER  NODE  SIGBMX     SIGAX    TAUMAX    SIGMAX    SIGMA1    SIGMA2    VMISES  VMISES/ALLOW  HINGE
  26     19    -2872.    -147.      -94.    -3019.        3.    -3022.     3024.      .04          0
  26     21    -1031.    -147.      -94.    -1178.        7.    -1186.     1190.      .02          0
  27     20    -4563.   -1653.     -727.    -6216.       84.    -6300.     6342.      .09          0
  27     22   -20197.   -1653.     -727.   -21851.       24.   -21875.    21887.      .32          0
  28     21     4025.    1504.     -292.     5529.     5545.      -15.     5552.      .08          0
  28     23    13455.    1504.     -292.    14959.    14965.       -6.    14968.      .22          0
  29     22    13457.    4311.     -463.    17768.    17780.      -12.    17786.      .26          0
  29     24    12743.    4311.     -463.    17054.    17067.      -13.    17073.      .25          0
  30     23   -12724.   -4506.      277.   -17230.        4.   -17234.    17237.      .25          0
  30     25   -12194.   -4506.      277.   -16700.        5.   -16705.    16707.      .25          0
  31     18     -663.   -3293.    -2116.    -3956.      918.    -4875.     5393.      .08          0
  31     22   -13121.   -3293.    -2116.   -16414.      268.   -16683.    16818.      .25          0
  32     19    -2035.     -52.    -1813.    -2087.     1048.    -3135.     3770.      .06          0
  32     23    -6756.     -52.    -1813.    -6808.      453.    -7261.     7497.      .11          0
  33     18     -602.    -742.     2229.    -1344.     1656.    -3000.     4087.      .06          0
  33     24    -6946.    -742.     2229.    -7688.      599.    -8287.     8603.      .13          0
  34     19     1977.    1240.     1263.     3217.     3653.     -437.     3890.      .06          0
  34     25     9284.    1240.     1263.    10523.    10673.     -149.    10748.      .16          0
  35     20    -3462.   -1294.      878.    -4757.      157.    -4914.     4994.      .07          0
  35     24   -15962.   -1294.      878.   -17256.       45.   -17301.    17323.      .25          0
  36     21     3552.    1177.       92.     4729.     4731.       -2.     4732.      .07          0
  36     25    14281.    1177.       92.    15458.    15459.       -1.    15459.      .23          0
  37     22   -47858.   -1624.      311.   -49481.        2.   -49483.    49484.      .73          0
  37     26   -11234.   -1624.      311.   -12857.        7.   -12865.    12869.      .19          0
  38     23   -33160.   -1624.      311.   -34784.        3.   -34787.    34788.      .51          0
  38     26   -11234.   -1624.      311.   -12857.        7.   -12865.    12868.      .19          0
  39     24    35124.    1057.     1064.    36181.    36212.      -31.    36228.      .53          0
  39     27     3851.    1057.     1064.     4908.     5129.     -221.     5243.      .08          0
  40     25   -35242.   -1057.    -2183.   -36300.      131.   -36431.    36496.      .54          0
  40     28    -3761.   -1057.    -2183.    -4819.      842.    -5660.     6125.      .09          0
  41     27     3851.    1057.     1064.     4908.     5129.     -221.     5243.      .08          0
  41     29    45200.    1057.     1064.    46257.    46282.      -24.    46294.      .68          0
  42     28    -3761.   -1057.    -2183.    -4819.      842.    -5660.     6125.      .09          0
  42     30   -45141.   -1057.    -2183.   -46198.      103.   -46301.    46353.      .68          0
```

TABLE 6. - Output listing, example structure 1--Continued

```
MEMBER END REACTIONS-MEMBER COORDINATE SYSTEM (J LESS THAN K)
                                         J NODE                                                                          K NODE
MEMBER   X FORCE    Y FORCE    Z FORCE   X MOMENT   Y MOMENT   Z MOMENT     X FORCE    Y FORCE    Z FORCE   X MOMENT   Y MOMENT   Z MOMENT
   1     -3502.4      997.6     4248.6   -16165.8   -80283.3    19140.4      3502.4     -997.6    -4248.6    16165.8    11775.1    -3054.7
   2      3501.6     -993.8     4234.5     -986.2   -79812.3   -19209.7     -3501.6      993.8    -4234.5      986.2    11531.1     3184.9
   3     -3502.4      997.6     4248.6   -16165.8   -11775.1     3054.7      3502.4     -997.6    -4248.6    16165.8   -50360.3    11534.7
   4      3501.6     -993.8     4234.5     -986.2   -11531.1    -3184.9     -3501.6      993.8    -4234.5      986.2   -50398.4   -11349.2
   5     -9996.8      515.7     1981.6     5012.6    -9305.3   -19468.3      9996.8     -515.7    -1981.6    -5012.6    -6808.3    23662.2
   6     10482.8     -647.6      396.8     3533.4    -3717.7    18004.6    -10482.8      647.6     -396.8    -3533.4      491.4   -23270.8
   7      1287.4    -3340.0     3603.4     4139.5   -25015.7   -25202.7     -1287.4     3340.0    -3603.4    -4139.5     4296.4     5998.0
   8      -967.8     3194.5     1277.9     2708.7    -9391.0    24362.8       967.8    -3194.5    -1277.9    -2708.7     2043.1    -5994.7
   9     -3914.3     1112.7    -1387.0    -1210.2    -9149.0      589.6      3914.3    -1112.7     1387.0     1210.2    17124.4     5808.4
  10      1107.7    -1005.2    -1375.9    -1274.3    -3361.1      236.2     -1107.7     1005.2     1375.9     1274.3    11272.6    -6015.8
  11      4452.6      310.9    -2674.5    -4852.7    22586.8    -1762.1     -4452.6     -310.9     2674.5     4852.7    -7208.2     3549.9
  12     -4199.6      170.2    -2343.8    -1318.1    20745.8     3923.4      4199.6     -170.2     2343.8     1318.1    -7268.9    -2944.9
  13     -2771.2     1002.2     -510.4   -11725.9       19.4      351.7      2771.2    -1002.2      510.4    11725.9     4130.9     7798.0
  14      1631.6     -575.6    -1292.1    -7909.6     8563.3     2298.3     -1631.6      575.6     1292.1     7909.6     1943.5    -6979.1
  15     12110.4     -390.0     1322.0     5493.6   -25027.6    -6378.3    -12110.4      390.0    -1322.0    -5493.6    14277.4     3206.6
  16     -5140.3      705.9     -118.2     4455.2    -8735.8     9137.1      5140.3     -785.9      118.2    -4455.2     9697.0    -2746.2
  17      3351.9    -2974.1    -2043.6     2244.2    58401.9   -57259.6     -3351.9     2974.1     2043.6    -2244.2   -19062.1        7.4
  18      3351.7     2974.1    -2043.6     2244.2    20277.8    57244.8     -3351.7    -2974.1     2043.6    -2244.2    19062.0        7.4
  19      1046.0     -528.2     7600.8     -428.7   -42614.3   -11989.2     -1046.0      528.2    -7600.8      428.7   -50496.1     5518.5
  20     -1049.8      527.4      883.2     -400.8   -27936.7    11786.5      1049.8     -527.4     -883.2      400.8    11818.8    -2160.7
  21      1045.9     -528.2     7600.9     -428.7    50496.1    -5518.5     -1045.9      528.2     -977.7      428.7   -76231.9     2349.2
  22      1045.9     -528.2      977.8     -428.7    76232.0    -2349.2     -1045.9      528.2     5645.4      428.7   -62228.9     -820.2
  23      1045.9     -528.2    -5645.4     -428.7    62229.0      820.2     -1045.9      528.2     5645.4      428.7     6927.2    -7290.9
  24     -1049.7      527.4      883.2     -400.8   -11818.8     2160.7      1049.7     -527.4     -883.2      400.8    -4299.3     7465.1
  25     -2955.0      119.2     -402.9     -277.3    -2103.8     2651.4      2955.0     -119.2      402.9      277.3     4420.3    -1966.0
  26       295.6     -227.6     -330.7     -276.9     2507.2    -2501.8      -295.6      227.6      330.7      276.9     -605.3     1193.3
  27      3323.4     2720.9    -2021.1    -2148.9    -1824.5    -6132.8     -3323.4    -2720.9     2021.1     2148.9    13445.9    21777.9
  28     -3022.6    -2593.7      266.5     -863.7      878.4     6142.0      3022.6     2593.7     -266.5      863.7    -2410.8   -21055.5
  29     -8665.9      152.9     -713.2    -1368.5     4143.9   -19324.8      8665.9     -152.9      713.2     1368.5     1655.6    20567.9
  30      9056.3      -74.7      613.2      818.2    -3259.1    18931.9     -9056.3       74.7     -613.2     -818.2    -1727.6   -19539.3
  31      6619.0      862.0    -1809.8    -6257.2     -347.3     -809.7     -6619.0     -862.0     1809.8     6257.2    15063.7     7819.7
  32       104.5    -1210.0     -197.3    -5360.8     3065.7      483.0      -104.5     1210.0      197.3     5360.8    -1461.0   -10322.2
  33      1491.7     -643.0      717.7     6591.3      261.6      787.6     -1491.7      643.0     -717.7    -6591.3    -6097.5    -6016.0
  34     -2491.6      287.3     1279.7     3734.7     1933.9    -1514.1      2491.6     -287.3    -1279.7    -3734.7   -12340.3     3850.4
  35      2601.7     -933.9     2920.9     2595.7     5855.6     -182.8     -2601.7      933.9    -2920.9    -2595.7   -22650.6    -5187.3
  36     -2366.1      562.1     2692.0      273.0     5865.0     -329.6      2366.1     -562.1    -2692.0     -273.0   -21344.1     3561.8
  37      3263.6    -2652.8      666.3      918.5   -32407.5   -51056.5     -3263.6     2652.8     -666.3     -918.5    19581.1      -10.3
  38      3263.4     2652.8      666.3      918.5     6754.8    51077.0     -3263.4    -2652.8     -666.3     -918.5   -19581.1      -10.3
  39     -2124.5      379.4    -2380.9     3147.8    52191.4     9064.9      2124.5     -379.4     2380.9    -3147.8     6437.9      278.6
  40      2125.4     -383.3    -2379.0    -6455.1    52250.4    -9212.3     -2125.4      383.3     2379.0     6455.1     6333.2     -226.4
  41     -2124.5      379.4    -2380.9     3147.8    -6437.8     -278.6      2124.5     -379.4     2380.9    -3147.8    68638.3    10191.2
  42      2125.4     -383.3    -2379.0    -6455.1    -6333.1      226.4     -2125.4      383.3     2379.0     6455.1    68485.2   -10240.1
```

TABLE 6. - Output listing, example structure 1--Continued

```
 INPUT LOADS,GLOBAL COORDINATE SYSTEM

    X DIRECTION:       0. POUNDS
    Y DIRECTION:       0. POUNDS
    Z DIRECTION:   -1200. POUNDS


MAXIMUM LOAD THAT CANOPY CAN SUPPORT IN X DIRECTION IS       0.   POUNDS
MAXIMUM LOAD THAT CANOPY CAN SUPPORT IN Y DIRECTION IS       0.   POUNDS
MAXIMUM LOAD THAT CANOPY CAN SUPPORT IN Z DIRECTION IS   13243.   POUNDS

 WEIGHT OF BEAM ELEMENTS  = 273. POUNDS
 WEIGHT OF PLATE ELEMENTS =   0. POUNDS
 TOTAL CANOPY WEIGHT      = 273. POUNDS
```

Example 2.--4-Post ROPS With Beams and Plates

Node numbering and element numbering schemes for this four-post ROPS, with beam and plate elements, are shown in figures 26 and 27, respectively.

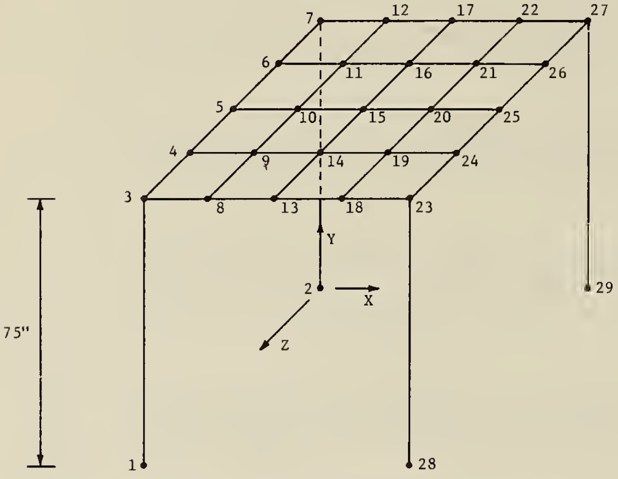


FIGURE 26. - Nodal numbers, example 2.

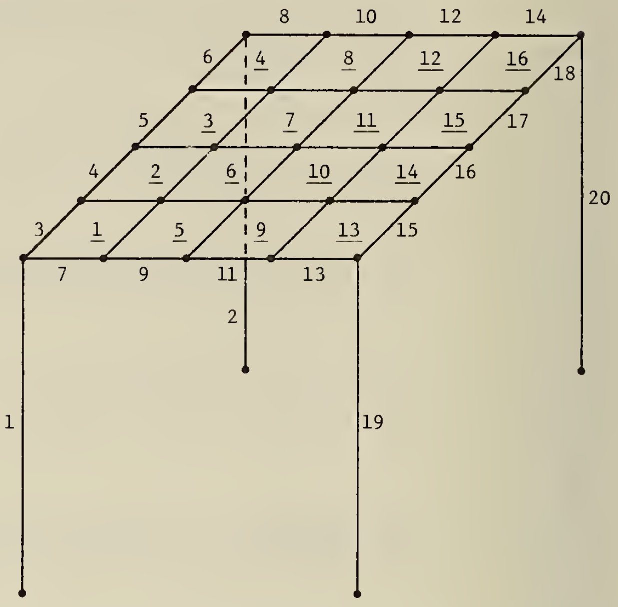
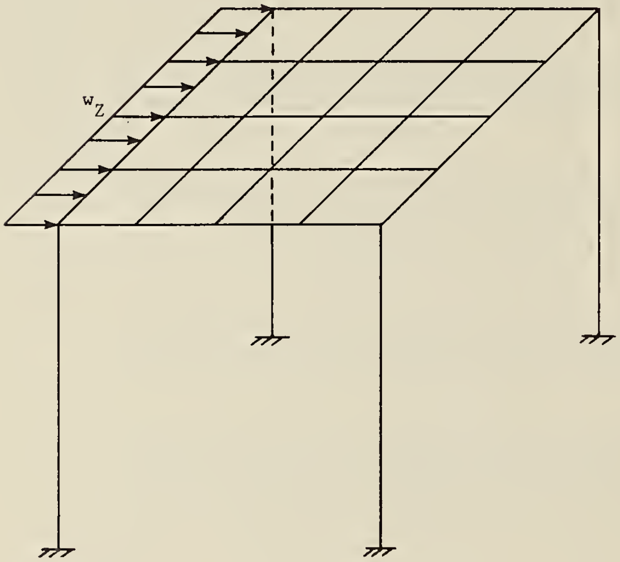
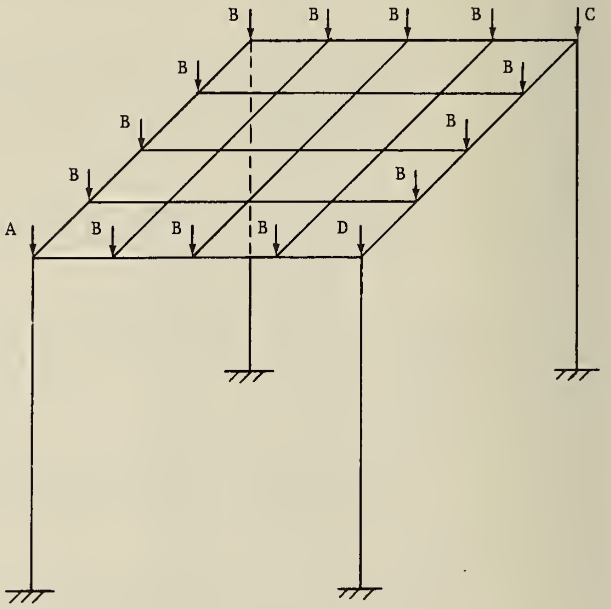


FIGURE 27. - Beam and plate element numbers, example 2



w_Z = 100 lb/in

FIGURE 28. - Load case 1, example 2.



A: F_Y = -100 lb
B: F_Y = -200 lb
C: F_Y = -1,500 lb
D: F_Y = -3,500 lb

FIGURE 29. - Load case 2, example 2.

The vertical posts and outer roof members and beam elements are made of 3- by 3- by 0.1875-inch structural tubing, and a 0.25-inch plate covers the roof. Two loading conditions, shown in figures 28 and 29, are applied; load case 1 is a plastic analysis without a user-defined deflection limitation, and load case 2 is an elastic analysis that includes a buckling analysis of beam members 1, 19, and 20.

Input data is presented in table 7, and output data appear in table 8.

TABLE 7. - Input cards for example structure 2

```
      EXAMPLE STRUCTURE 2   PLASTIC CANOPY PROGRAM        MARCH 15,1978
    1
    3   29    7    1   20   10   16    4    2 28500000.  11090000.
    1    2    0.0       0.0      40.0       0.0       0.0       0.0       1
    3    7    0.0      75.0      40.0       0.0      75.0       0.0       1
    8   12   10.0      75.0      40.0      10.0      75.0       0.0       1
   13   17   20.0      75.0      40.0      20.0      75.0       0.0       1
   18   22   30.0      75.0      40.0      30.0      75.0       0.0       1
   23   27   40.0      75.0      40.0      40.0      75.0       0.0       1
   28   29   40.0       0.0      40.0      40.0       0.0       0.0       1
    1    2  50000.0     3.0       3.0     0.1875    0.1875
    1    1    1    3    0    1    1
    2    2    2    7    0    1    1
    3    6    3    4    0    1    1
    7    8    3    8    0    1    4
    9   10    8   13    0    1    4
   11   12   13   18    0    1    4
   13   14   18   23    0    1    4
   15   18   23   24    0    1    1
   19   19   23   28    0    1    1    0    0    0    0    0    1
   20   20   27   29    0    1    1    0    0    0    0    0    1
    1    3    8    9    4    1    0.25
    4    6   11   12    7    1    0.25
    8   11   16   17   12    1    0.25
   12   16   21   22   17    1    0.25
   16   21   26   27   22    1    0.25
    1    1    1    1    1    1    1
    2    1    1    1    1    1    1
   28    1    1    1    1    1    1
   29    1    1    1    1    1    1
    0    1
    3    6    1   100.0
    0    0.0       0    0
    7    0
    3    7    4    0.0     -100.0
    4    6    1    0.0     -200.0
   24   26    1    0.0     -200.0
    8   18    5    0.0     -200.0
   12   22    5    0.0     -200.0
   23   23    1    0.0    -3500.0
   27   27    1    0.0    -1500.0
    1    3    1    1
   27   29   20   20
   23   28   19   19
```

TABLE 8. - Output listing, example structure 2

```
                    - -  P L A S T I C   C A N O P Y   R E S U L T S  - -

EXAMPLE STRUCTURE 2   PLASTIC CANOPY PROGRAM        MARCH 15,1978


  • •  S T R U C T U R E   D A T A

       NUMBER OF JOINTS=  29

       NUMBER OF JT. OESIGNATION CARDS=   7

       NUMBER OF BEAM GEOMETRIES=   1

       NUMBER OF BEAM ELEMENTS=  20

       NUMBER OF BEAM ELEMENT DESIGNATION CARDS=  10

       NUMBER OF PLATE ELEMENTS=  16

       NUMBER OF RESTRAINED JOINTS=   4

       NUMBER OF LOADING CONDITIONS=   2

       NUMBER OF STRUCTURE GEOMETRIES=   2

       YOUNG S MODULUS FOR BEAMS= 28500000.

       SHEAR MOOULUS FOR BEAMS= 11090000.

       YOUNG S MOOULUS FOR PLATES= 28500000.

       POISSON RATIO FOR PLATES= .28


  • •  P R O G R A M   O P T I O N S

       PLASTIC ANALYSIS:  YES

       PLOT UNOEFORMED GEOMETRY:   NO

       PLOT OEFORMEO GEOMETRY:   NO

       NO. OF BUCKLING ELEMENTS:   0
```

TABLE 8. - Output listing, example structure 2--Continued

```
    - - O U T P U T   A B B R E V I A T I O N S


ABBREVIATIONS USEO IN BEAM MEMBER PROPERTIES TABLE

    JJ =NOOAL NUMBER OF BEAM ENDPOINT
    JK =NODAL NUMBER OF BEAM ENDPOINT
    AX =CROSS SECTIONAL AREA
    IX =TORSIONAL MOMENT OF INERTIA
    IY =BENOING MOMENT OF INERTIA,LOCAL Y-AXIS
    IZ =BENOING MOMENT OF INERTIA,LOCAL Z-AXIS
    AA =FLAG DENOTING BEAM ELEMENT ROTATION
    ACX=OISTANCE TO EXTREME FIBER,TORSION
    ACY=OISTANCE TO EXTREME FIBER,M(Z)
    ACZ=DISTANCE TO EXTREME FIBER,M(Y)
    F  =GEOMETRIC FORM FACTOR,SHEAR DEFORMATIONS
    BM =RATIO OF PLASTIC TO ELASTIC BENDING MOOULUS
    YIELO=MATERIAL YIELD STRESS,PSI
    L  =MEMBER LENGTH,INCHES
    CX =DIRECTION COSINE
    CY =OIRECTION COSINE
    CZ =OIRECTION COSINE


ABBREVIATIONS USEO IN BEAM MEMBER STRESS TABLE

    SIGBMX=COMBINED BENDING STRESS ABOUT PRINCIPAL AXES
    SIGAX =AXIAL STRESS
    TAUMAX=TORSIONAL SHEAR STRESS
    SIGMAX=BENOING PLUS AXIAL STRESS
    SIGMA1=PRINCIPAL STRESS
    SIGMA2=PRINCIPAL STRESS
    VMISES=VON MISES EFFECTIVE STRESS
    VMISES/ALLOW=RATIO VON MISES TO MATERIAL YIELO STRESS
    HINGE =NON ZERO ENTRY OENOTES PLASTIC HINGE
```

TABLE 8. - Output listing, example structure 2--Continued

```
COORDINATES OF JOINTS
JOINT        X         Y         Z
   1       .00       .00     40.00
   2       .00       .00       .00
   3       .00     75.00     40.00
   4       .00     75.00     30.00
   5       .00     75.00     20.00
   6       .00     75.00     10.00
   7       .00     75.00       .00
   8     10.00     75.00     40.00
   9     10.00     75.00     30.00
  10     10.00     75.00     20.00
  11     10.00     75.00     10.00
  12     10.00     75.00       .00
  13     20.00     75.00     40.00
  14     20.00     75.00     30.00
  15     20.00     75.00     20.00
  16     20.00     75.00     10.00
  17     20.00     75.00       .00
  18     30.00     75.00     40.00
  19     30.00     75.00     30.00
  20     30.00     75.00     20.00
  21     30.00     75.00     10.00
  22     30.00     75.00       .00
  23     40.00     75.00     40.00
  24     40.00     75.00     30.00
  25     40.00     75.00     20.00
  26     40.00     75.00     10.00
  27     40.00     75.00       .00
  28     40.00       .00     40.00
  29     40.00       .00       .00
```

TABLE 8. - Output listing, example structure 2--Continued

```
MEMBER DESIGNATIONS,PROPERTIES,AND ORIENTATIONS
MEMBER JJ   JK   AX    IX    IY    IZ    AA  ACX   ACY   ACZ    F     BM   YIELD    L       CX     CY     CZ
   1    1    3  1.97  4.17  2.51  2.51   0  1.41  1.50  1.50  1.87  1.21  50000.  75.00    .00   1.00    .00
   2    2    7  1.97  4.17  2.51  2.51   0  1.41  1.50  1.50  1.87  1.21  50000.  75.00    .00   1.00    .00
   3    3    4  1.97  4.17  2.51  2.51   0  1.41  1.50  1.50  1.87  1.21  50000.  10.00    .00    .00  -1.00
   4    4    5  1.97  4.17  2.51  2.51   0  1.41  1.50  1.50  1.87  1.21  50000.  10.00    .00    .00  -1.00
   5    5    6  1.97  4.17  2.51  2.51   0  1.41  1.50  1.50  1.87  1.21  50000.  10.00    .00    .00  -1.00
   6    6    7  1.97  4.17  2.51  2.51   0  1.41  1.50  1.50  1.87  1.21  50000.  10.00    .00    .00  -1.00
   7    3    8  1.97  4.17  2.51  2.51   0  1.41  1.50  1.50  1.87  1.21  50000.  10.00   1.00    .00    .00
   8    7   12  1.97  4.17  2.51  2.51   0  1.41  1.50  1.50  1.87  1.21  50000.  10.00   1.00    .00    .00
   9    8   13  1.97  4.17  2.51  2.51   0  1.41  1.50  1.50  1.87  1.21  50000.  10.00   1.00    .00    .00
  10   12   17  1.97  4.17  2.51  2.51   0  1.41  1.50  1.50  1.87  1.21  50000.  10.00   1.00    .00    .00
  11   13   18  1.97  4.17  2.51  2.51   0  1.41  1.50  1.50  1.87  1.21  50000.  10.00   1.00    .00    .00
  12   17   22  1.97  4.17  2.51  2.51   0  1.41  1.50  1.50  1.87  1.21  50000.  10.00   1.00    .00    .00
  13   18   23  1.97  4.17  2.51  2.51   0  1.41  1.50  1.50  1.87  1.21  50000.  10.00   1.00    .00    .00
  14   22   27  1.97  4.17  2.51  2.51   0  1.41  1.50  1.50  1.87  1.21  50000.  10.00   1.00    .00    .00
  15   23   24  1.97  4.17  2.51  2.51   0  1.41  1.50  1.50  1.87  1.21  50000.  10.00    .00    .00  -1.00
  16   24   25  1.97  4.17  2.51  2.51   0  1.41  1.50  1.50  1.87  1.21  50000.  10.00    .00    .00  -1.00
  17   25   26  1.97  4.17  2.51  2.51   0  1.41  1.50  1.50  1.87  1.21  50000.  10.00    .00    .00  -1.00
  18   26   27  1.97  4.17  2.51  2.51   0  1.41  1.50  1.50  1.87  1.21  50000.  10.00    .00    .00  -1.00
  19   23   28  1.97  4.17  2.51  2.51   0  1.41  1.50  1.50  1.87  1.21  50000.  75.00    .00  -1.00    .00
  20   27   29  1.97  4.17  2.51  2.51   0  1.41  1.50  1.50  1.87  1.21  50000.  75.00    .00  -1.00    .00
```

```
THIN PLATE/SHELL ELEMENT DATA

ELEMENT                                                  NORMAL
 NUMBER   NODE-I   NODE-J   NODE-K   NODE-L   THICKNESS  PRESSURE

     1        3        8        9        4      .2500        .00
     2        4        9       10        5      .2500        .00
     3        5       10       11        6      .2500        .00
     4        6       11       12        7      .2500        .00
     5        8       13       14        9      .2500        .00
     6        9       14       15       10      .2500        .00
     7       10       15       16       11      .2500        .00
     8       11       16       17       12      .2500        .00
     9       13       18       19       14      .2500        .00
    10       14       19       20       15      .2500        .00
    11       15       20       21       16      .2500        .00
    12       16       21       22       17      .2500        .00
    13       18       23       24       19      .2500        .00
    14       19       24       25       20      .2500        .00
    15       20       25       26       21      .2500        .00
    16       21       26       27       22      .2500        .00
```

TABLE 8. - Output listing, example structure 2--Continued

```
JOINT RESTRAINTS
     JOINT  X TRANS.  Y TRANS.  Z TRANS.  X ROTA.  Y ROTA.  Z ROTA.
       1        1         1         1        1        1        1
       2        1         1         1        1        1        1
      28        1         1         1        1        1        1
      29        1         1         1        1        1        1


 E Q U A T I O N   P A R A M E T E R S

  TOTAL NUMBER OF EQUATIONS =  174
  BANDWIDTH                 =   42
  NUMBER OF EQNS IN A BLOCK =   34
  NUMBER OF BLOCKS          =    6


   LOADING NUMBER  1

   NO. OF LOADED JOINT CARDS  =  0
   NO. OF LOADED MEMBER CARDS =  1

 DISTRIBUTED LOADS ON MEMBERS
 MEMBER     WX          WY         WZ
    3    100.00        .00        .00
    4    100.00        .00        .00
    5    100.00        .00        .00
    6    100.00        .00        .00
```

TABLE 8. - Output listing, example structure 2--Continued

```
JOINT DISPLACEMENTS
JOINT  X TRANS.  Y TRANS.  Z TRANS.   X ROTA.   Y ROTA.   Z ROTA.
   1   .000000   .000000  -.000000   .000006  -.000014  -.045303
   2   .000000   .000000   .000000   .000018   .000011  -.045296
   3  3.271730   .006513   .000396   .000051  -.000104  -.009775
   4  3.272520   .007083   .000463   .000044  -.000046  -.009588
   5  3.272674   .007329   .000571  -.000000   .000000  -.009529
   6  3.272513   .007078   .000680  -.000044   .000047  -.009589
   7  3.271716   .006515   .000746  -.000049   .000105  -.009777
   8  3.271891  -.030945   .000707   .000034  -.000005   .000346
   9  3.272274  -.031399   .000661  -.000056   .000000   .000980
  10  3.272432  -.031583   .000568  -.000001   .000000   .000884
  11  3.272268  -.031416   .000475   .000055   .000000   .000979
  12  3.271877  -.030956   .000429  -.000031   .000005   .000346
  13  3.271933  -.000787   .000676   .000003   .000006   .003747
  14  3.272122  -.000772   .000643   .000000   .000000   .004392
  15  3.272221  -.000779   .000564  -.000001   .000000   .004372
  16  3.272115  -.000793   .000486  -.000001   .000000   .004392
  17  3.271919  -.000798   .000453   .000001  -.000005   .003747
  18  3.271882   .029763   .000622  -.000027   .000002   .000425
  19  3.272041   .030248   .000596   .000056   .000000   .001058
  20  3.272118   .030420   .000561  -.000001   .000000   .000964
  21  3.272034   .030227   .000525  -.000057   .000000   .001058
  22  3.271868   .029759   .000499   .000032  -.000002   .000426
  23  3.271762  -.006515   .000660  -.000045  -.000016  -.009617
  24  3.272014  -.007056   .000624  -.000044  -.000018  -.009431
  25  3.272082  -.007308   .000557  -.000001   .000000  -.009371
  26  3.272007  -.007074   .000490   .000043   .000019  -.009431
  27  3.271748  -.006512   .000454   .000051   .000017  -.009617
  28   .000000  -.000000   .000000   .000000  -.000000  -.000000
  29   .000000  -.000000  -.000000  -.000000   .000000  -.000000


REACTIONS AT RESTRAINED JOINTS
JOINT  X FORCE     Y FORCE     Z FORCE    X MOMENT    Y MOMENT    Z MOMENT
   1    -2618.4     -4872.4         3.4        76.1        56.8     98638.6
   2    -2618.9     -4873.7        -3.7       -88.0       -47.8     98658.2
  28    -1295.6      4874.3        -4.8      -135.1         9.9          .0
  29    -1295.7      4871.8         3.0        61.7       -10.3          .0
```

TABLE 8. - Output listing, example structure 2--Continued

```
                              MEMBER STRESSES

MEMBER  NODE  SIGBMX    SIGAX   TAUMAX   SIGMAX    SIGMA1    SIGMA2   VMISES  VMISES/ALLOW  HINGE
   1      1   50000.    2475.     19.    50000.    50000.      -0.    50000.      1.00        1
   1      3   50000.    2475.     19.    50000.    50000.      -0.    50000.      1.00        2
   2      2   50000.    2476.    -16.    50000.    50000.      -0.    50000.      1.00        1
   2      7   50000.    2476.    -16.    50000.    50000.      -0.    50000.      1.00        2
   3      3    -906.    -189.    291.    -1095.       78.    -1173.    1215.       .02        0
   3      4    -844.    -189.    291.    -1032.       82.    -1115.    1159.       .02        0
   4      4    -832.    -310.     92.    -1142.        8.    -1150.    1154.       .02        0
   4      5   -1127.    -310.     92.    -1437.        7.    -1443.    1446.       .02        0
   5      5   -1127.    -310.    -94.    -1437.        7.    -1443.    1447.       .02        0
   5      6    -827.    -310.    -94.    -1137.        8.    -1145.    1150.       .02        0
   6      6    -838.    -189.   -293.    -1027.       84.    -1110.    1155.       .02        0
   6      7    -915.    -189.   -293.    -1104.       78.    -1182.    1224.       .02        0
   7      3   50000.     459.     28.    50000.    50000.      -99.   50000.       .97        4
   7      8   29026.     459.     28.    29485.    33454.    -3969.   37424.       .62        0
   8      7   50000.     460.    -29.    50000.    50000.     -100.   50000.       .97        4
   8     12   29031.     460.    -29.    29491.    33459.    -3969.   37428.       .62        0
   9      8   17892.     119.     48.    18011.    27541.    -9530.   37071.       .61        0
   9     13     198.     119.     48.      317.     8264.    -7947.   16208.       .27        0
  10     12   17896.     119.    -49.    18015.    27545.    -9530.   37075.       .61        0
  10     17     201.     119.    -49.      320.     8265.    -7945.   16208.       .27        0
  11     13  -15928.    -144.     48.   -16072.        2.   -16074.   16075.       .27        0
  11     18  -28563.    -144.     48.   -28707.        0.   -28707.   28707.       .47        0
  12     17  -15928.    -144.    -49.   -16072.        2.   -16074.   16075.       .27        0
  12     22  -28563.    -144.    -49.   -28707.        0.   -28707.   28707.       .47        0
  13     18  -28649.    -342.     28.   -28991.        0.   -28991.   28991.       .48        0
  13     23  -50000.    -342.     28.   -50000.        0.   -50000.   50000.       .95        0
  14     22  -28648.    -342.    -30.   -28990.        0.   -28990.   28990.       .48        0
  14     27  -50000.    -342.    -30.   -50000.        0.   -50000.   50000.       .95        0
  15     23     262.     102.    291.      364.      528.     -164.     628.       .01        0
  15     24     260.     102.    291.      362.      524.     -162.     621.       .01        0
  16     24     249.     191.     93.      440.      459.      -19.     469.       .01        0
  16     25     272.     191.     93.      462.      481.      -19.     491.       .01        0
  17     25     271.     191.    -92.      462.      481.      -19.     491.       .01        0
  17     26     267.     191.    -92.      458.      476.      -18.     485.       .01        0
  18     26     277.     102.   -290.      380.      537.     -157.     631.       .01        0
  18     27     228.     102.   -290.      330.      501.     -171.     606.       .01        0
  19     23  -50000.   -2476.      3.   -50000.        0.   -50000.   50000.      1.00        3
  19     28     -81.   -2476.      3.    -2556.        0.    -2556.    2556.       .04        0
  20     27  -50000.   -2475.     -3.   -50000.        0.   -50000.   50000.      1.00        3
  20     29     -37.   -2475.     -3.    -2511.        0.    -2511.    2511.       .04        0
```

TABLE 8. - Output listing, example structure 2--Continued

```
MEMBER END REACTIONS-MEMBER COORDINATE SYSTEM (J LESS THAN K)
                                          J NODE                                                                K NODE
MEMBER    X FORCE    Y FORCE    Z FORCE   X MOMENT   Y MOMENT   Z MOMENT     X FORCE    Y FORCE    Z FORCE   X MOMENT   Y MOMENT   Z MOMENT
   1      -4872.4     2618.4        3.4       56.8      -76.1    98638.6      4872.4    -2618.4       -3.4      -56.8     -178.1    97738.9
   2      -4873.7     2618.9       -3.7      -47.8       88.0    98658.2      4873.7    -2618.9        3.7       47.8      192.3    97756.8
   3        371.8      -45.5    -1012.6      863.6     1341.5     -177.8      -371.8       45.5     -971.7     -863.6    -1137.4     -277.0
   4        609.5      -12.4     -955.2      274.1     1136.9      258.8      -609.5       12.4    -1029.1     -274.1    -1506.5     -383.0
   5        609.8       13.3    -1029.0     -279.0     1506.1      382.9      -609.8      -13.3     -955.2      279.0    -1137.1     -249.6
   6        372.3       46.4     -972.1     -868.5     1136.9      267.8      -372.3      -46.4    -1012.2      868.5    -1337.6      196.0
   7       -904.4    -4799.8      114.8       82.5    -1284.9   -96535.2       904.4     4799.8     -114.8      -82.5      136.5    48537.2
   8       -905.8    -4800.2     -115.3      -86.5     1209.4   -96548.3       905.8     4800.2      115.3       86.5     -136.2    48546.0
   9       -233.6    -4804.1       12.7      140.9     -136.6   -48393.0       233.6     4804.1      -12.7     -140.9       10.0      351.6
  10       -233.7    -4804.6      -12.6     -145.2      136.2   -48401.8       233.7     4804.6       12.6      145.2       -9.9      356.3
  11        283.6    -4804.2        6.7      141.2      -10.1     -211.9      -283.6     4804.2       -6.7     -141.2      -56.5   -47829.6
  12        283.5    -4804.5       -6.7     -145.8       10.0     -216.7      -283.5     4804.5        6.7      145.8       56.8   -47828.7
  13        673.4    -4799.8       15.1       83.4       56.4    47973.8      -673.4     4799.8      -15.1      -83.4     -207.2   -95971.9
  14        673.1    -4800.2      -15.0      -88.3      -56.7    47972.9      -673.1     4800.2       15.0       88.3      206.9   -95974.7
  15       -200.5       47.4      -40.2      862.1      216.2      222.9       200.5      -47.4       40.2     -862.1      185.3      250.8
  16       -375.4       14.3       10.6      275.7     -185.5     -232.6       375.4      -14.3      -10.6     -275.7       79.6      375.6
  17       -376.0      -11.5      -10.7     -274.3      -79.3     -375.6       376.0       11.5       10.7      274.3      186.0      261.1
  18       -201.5      -44.5       40.2     -860.7     -185.8     -279.4       201.5       44.5      -40.2      860.7     -216.2     -165.7
  19       4874.3     1295.6        4.8        9.9     -222.0    97172.5     -4874.3    -1295.6       -4.8       -9.9     -135.1         .0
  20       4871.8     1295.7       -3.0      -10.3      159.6    97173.8     -4871.8    -1295.7        3.0       10.3       61.7         .0
```

TABLE 8. - Output listing, example structure 2--Continued

```
SHELL ELEMENT STRESSES

ELEMENT   MEMBRANE STRESS COMPONENTS     BENDING STRESS COMPONENTS            COMBINED STRESS COMPONENTS
NUMBER       SXX       SYY       SXY       MXX       MYY       MXY              XX        YY        XY

     1    -139.7     -68.9     368.8    4005.4    1124.2    -182.6   (+)   -4145.1   -1193.0     186.3
                                                                     (-)    3865.7    1055.3     551.4
     2    -761.6    -239.6      65.0    4068.0    1160.9     -16.7   (+)   -4829.5   -1400.5      48.3
                                                                     (-)    3306.4     921.3      81.6
     3    -761.5    -239.6     -64.6    4068.1    1161.2      16.4   (+)   -4829.6   -1400.8     -48.2
                                                                     (-)    3306.6     921.7     -81.0
     4    -139.3     -68.8    -369.0    4006.1    1125.4     182.6   (+)   -4145.4   -1194.1    -186.4
                                                                     (-)    3866.7    1056.6    -551.5
     5    -137.7      72.8     344.0    1315.7     358.4    -141.8   (+)   -1453.4    -285.7     202.3
                                                                     (-)    1178.0     431.2     485.8
     6    -488.7     105.2     154.5    1340.5     391.5      23.0   (+)   -1829.1    -286.3     177.5
                                                                     (-)     851.8     496.7     131.5
     7    -488.7     105.3    -154.1    1340.8     392.0     -23.1   (+)   -1829.5    -286.7    -177.2
                                                                     (-)     852.1     497.3    -131.0
     8    -137.6      72.9    -344.2    1316.5     360.2     141.9   (+)   -1454.1    -287.4    -202.3
                                                                     (-)    1178.8     433.1    -486.1
     9    -178.1      32.8     248.2   -1285.8    -352.0    -141.7   (+)    1107.7     384.8     106.5
                                                                     (-)   -1463.9    -319.2     390.0
    10    -235.5      95.8     125.8   -1310.2    -383.9      23.1   (+)    1074.7     479.7     148.9
                                                                     (-)   -1545.8    -288.1     102.8
    11    -235.3      95.8    -125.4   -1310.0    -383.2     -23.0   (+)    1074.6     479.1    -148.4
                                                                     (-)   -1545.3    -287.4    -102.3
    12    -178.0      32.8    -248.2   -1285.1    -349.9     141.9   (+)    1107.1     382.7    -106.3
                                                                     (-)   -1463.1    -317.1    -390.1
    13    -200.2      30.8     191.2   -3975.6   -1117.5    -182.6   (+)    3775.4    1148.3       8.6
                                                                     (-)   -4175.8   -1086.8     373.8
    14     -51.8     131.2      66.8   -4037.9   -1153.3     -16.6   (+)    3986.2    1284.5      50.2
                                                                     (-)   -4089.7   -1022.1      83.5
    15     -51.9     131.4     -66.3   -4037.7   -1152.5      16.6   (+)    3985.8    1284.0     -49.8
                                                                     (-)   -4089.5   -1021.1     -82.9
    16    -200.1      31.1    -191.1   -3975.0   -1115.3     182.7   (+)    3774.9    1146.4      -8.4
                                                                     (-)   -4175.0   -1084.2    -373.8
```

TABLE 8. - Output listing, example structure 2--Continued

```
PRINCIPAL SHELL ELEMENT STRESSES

ELEMENT         COMBINED STRESS COMPONENTS      PRINCIPAL STRESS COMPONENTS      PRINCIPAL DIRECTION        VON MISES
NUMBER          XX          YY          XY          S1          S2                     THETA                  STRESS

   1    (+)  -4145.1     -1193.0      186.3     -1181.3     -4156.8                   -.0628                  3710.0
        (-)   3865.7      1055.3      551.4      3970.1       951.0                    .1870                  3590.3
   2    (+)  -4829.5     -1400.5       48.3     -1399.9     -4830.2                   -.0141                  4304.5
        (-)   3306.4       921.3       81.6      3309.2       918.5                    .0342                  2958.9
   3    (+)  -4829.6     -1400.8      -48.2     -1400.1     -4830.3                    .0141                  4304.5
        (-)   3306.6       921.7      -81.0      3309.3       918.9                   -.0339                  2958.9
   4    (+)  -4145.4     -1194.1     -186.4     -1182.4     -4157.1                    .0628                  3710.0
        (-)   3866.7      1056.6     -551.5      3971.1       952.2                   -.1870                  3591.0
   5    (+)  -1453.4      -285.7      202.3      -251.6     -1487.4                   -.1667                  1378.9
        (-)   1178.0       431.2      485.8      1417.3       191.9                    .4578                  1331.7
   6    (+)  -1829.1      -286.3      177.5      -266.1     -1849.3                   -.1131                  1731.6
        (-)    851.8       496.7      131.5       895.2       453.3                    .3187                   775.3
   7    (+)  -1829.5      -286.7     -177.2      -266.6     -1849.6                    .1129                  1731.7
        (-)    852.1       497.3     -131.0       895.2       454.2                   -.3180                   775.3
   8    (+)  -1454.1      -287.4     -202.3      -253.3     -1488.2                    .1669                  1379.1
        (-)   1178.8       433.1     -486.1      1418.6       193.3                   -.4582                  1332.5
   9    (+)   1107.7       384.8      106.5      1123.1       369.4                    .1433                   991.4
        (-)  -1463.9      -319.2      390.0      -198.9     -1584.1                   -.2991                  1494.6
  10    (+)   1074.7       479.7      148.9      1109.9       444.5                    .2320                   967.5
        (-)  -1545.8      -288.1      102.8      -279.8     -1554.1                   -.0810                  1434.8
  11    (+)   1074.6       479.1     -148.4      1109.6       444.1                   -.2311                   967.3
        (-)  -1545.3      -287.4     -102.3      -279.1     -1553.6                    .0806                  1434.6
  12    (+)   1107.1       382.7     -106.3      1122.3       367.4                   -.1427                   991.1
        (-)  -1463.1      -317.1     -390.1      -196.9     -1583.3                    .2989                  1494.6
  13    (+)   3775.4      1148.3        8.6      3775.4      1148.3                    .0033                  3352.2
        (-)  -4175.8     -1086.8      373.8     -1042.2     -4220.4                   -.1187                  3807.8
  14    (+)   3986.2      1284.5       50.2      3987.1      1283.6                    .0186                  3525.2
        (-)  -4089.7     -1022.1       83.5     -1019.8     -4092.0                   -.0272                  3689.3
  15    (+)   3985.8      1284.0      -49.8      3986.8      1283.1                   -.0184                  3524.9
        (-)  -4089.5     -1021.1      -82.9     -1018.9     -4091.8                    .0270                  3689.4
  16    (+)   3774.9      1146.4       -8.4      3774.9      1146.4                   -.0032                  3352.1
        (-)  -4175.0     -1084.2     -373.8     -1039.6     -4219.6                    .1186                  3807.8
```

TABLE 8. - Output listing, example structure 2--Continued

```
 INPUT LOAOS,GLOBAL COOROINATE SYSTEM

    X OIRECTION:    4000. POUNOS
    Y DIRECTION:       0. POUNOS
    Z DIRECTION:       0. POUNDS


MAXIMUM LOAD THAT CANOPY CAN SUPPORT IN X DIRECTION IS  -7829.  POUNDS
MAXIMUM LOAD THAT CANOPY CAN SUPPORT IN Y DIRECTION IS     -0.  POUNOS
MAXIMUM LOAD THAT CANOPY CAN SUPPORT IN Z DIRECTION IS     -2.  POUNDS

  WEIGHT OF BEAM ELEMENTS  = 257. POUNDS
  WEIGHT OF PLATE ELEMENTS = 113. POUNDS
  TOTAL CANOPY WEIGHT      = 370. POUNDS


          * * *  P L A S T I C   A N A L Y S I S   S U M M A R Y



   APPLIED LOADS AT ELASTIC LIMIT: F(X)=   6176.
                                   F(Y)=      0.
                                   F(Z)=      0.

   APPLIED LOADS AT ULTIMATE:      F(X)=   7829.
                                   F(Y)=      0.
                                   F(Z)=      2.


               LOADING SUMMARY

  LOAD          APPLIED LOADS (LBS)        DEFLECTION,INCHES,NODE  0     ENERGY (IN-LB)
 INCREMENT     F(X)      F(Y)      F(Z)     GLOBAL   DIRECTION
     1         6176.       0.        0.                 .0000                 4826.
     2         7197.       0.        0.                 .0000                 9048.
     3         7937.       0.        0.                 .0000                17205.
     4         7937.       0.        0.                 .0000                17205.
```

TABLE 8. - Output listing, example structure 2--Continued

```
  • •  P R O G R A M   O P T I O N S

         PLASTIC ANALYSIS:   NO

         PLOT UNOEFORMEO GEOMETRY:   NO

         PLOT DEFORMEO GEOMETRY:   NO

         NO. OF BUCKLING ELEMENTS:   3


 LOAOING NUMBER  2

 NO. OF LOAOED JOINT CARDS  =  7
 NO. OF LOAOEO MEMBER CARDS =  0

ACTIONS APPLIEO AT JOINTS
JOINT   X FORCE   Y FORCE   Z FORCE  X MOMENT  Y MOMENT  Z MOMENT
   3        0.      -100.       0.        0.        0.        0.
   7        0.      -100.       0.        0.        0.        0.
   4        0.      -200.       0.        0.        0.        0.
   5        0.      -200.       0.        0.        0.        0.
   6        0.      -200.       0.        0.        0.        0.
  24        0.      -200.       0.        0.        0.        0.
  25        0.      -200.       0.        0.        0.        0.
  26        0.      -200.       0.        0.        0.        0.
   8        0.      -200.       0.        0.        0.        0.
  13        0.      -200.       0.        0.        0.        0.
  18        0.      -200.       0.        0.        0.        0.
  12        0.      -200.       0.        0.        0.        0.
  17        0.      -200.       0.        0.        0.        0.
  22        0.      -200.       0.        0.        0.        0.
  23      100.     -3500.       0.        0.        0.        0.
  27      100.     -1500.       0.        0.        0.        0.


REACTIONS AT RESTRAINED JOINTS
JOINT  X FORCE      Y FORCE     Z FORCE    X MOMENT    Y MOMENT   Z MOMENT
   1     -654.1      6673.1      -296.4     -7656.5        38.0    33211.1
   2     -691.0      6433.9       265.4      6292.4        24.1    34180.2
  28     -414.8     46564.0      -267.3     -6986.3        24.0         .0
  29     -434.5     24672.3       298.2      7054.9        38.2         .0
```

TABLE 8. - Output listing, example structure 2--Continued

```
                              MEMBER STRESSES

MEMBER  NODE  SIGBMX     SIGAX    TAUMAX    SIGMAX    SIGMA1    SIGMA2    VMISES  VMISES/ALLOW  HINGE
   1      1   -24377.    -3390.      13.   -27766.       0.   -27766.    27766.      .56        0
   1      3   -18144.    -3390.      13.   -21534.       0.   -21534.    21534.      .43        0
   2      2   -24141.    -3268.       8.   -27409.       0.   -27409.    27409.      .55        0
   2      7   -18646.    -3268.       8.   -21914.       0.   -21914.    21914.      .44        0
   3      3    -9066.     -120.     299.    -9187.      10.    -9196.     9201.      .18        0
   3      4   -10992.     -120.     299.   -11112.       8.   -11120.    11124.      .22        0
   4      4   -11017.     -119.     227.   -11137.       5.   -11141.    11144.      .22        0
   4      5   -17789.     -119.     227.   -17908.       3.   -17911.    17912.      .36        0
   5      5   -17790.     -118.     115.   -17908.       1.   -17909.    17909.      .36        0
   5      6   -11616.     -118.     115.   -11733.       1.   -11735.    11735.      .23        0
   6      6   -11593.     -115.      37.   -11707.       0.   -11708.    11708.      .23        0
   6      7    -7848.     -115.      37.    -7963.       0.    -7963.     7963.      .16        0
   7      3     8938.      209.    -219.     9147.    9152.       -5.     9155.      .18        0
   7      8    21954.      209.    -219.    22163.   22165.       -2.    22167.      .44        0
   8      7    10624.      219.    -142.    10843.   10845.       -2.    10845.      .22        0
   8     12    22810.      219.    -142.    23029.   23030.       -1.    23031.      .46        0
   9      8    21956.      185.    -199.    22142.   22143.       -2.    22144.      .44        0
   9     13    21719.      185.    -199.    21904.   21906.       -2.    21907.      .44        0
  10     12    22809.      190.    -166.    23000.   23001.       -1.    23001.      .46        0
  10     17    21780.      190.    -166.    21970.   21971.       -1.    21972.      .44        0
  11     13    21700.      189.    -142.    21888.   21889.       -1.    21890.      .44        0
  11     18     8440.      189.    -142.     8629.    8631.       -2.     8632.      .17        0
  12     17    21757.      189.    -223.    21946.   21949.       -2.    21950.      .44        0
  12     22     7705.      189.    -223.     7894.    7900.       -6.     7904.      .16        0
  13     18     8398.      220.    -126.     8618.    8620.       -2.     8621.      .17        0
  13     23    18138.      220.    -126.    18357.   18358.       -1.    18359.      .37        0
  14     22     7660.      215.    -232.     7875.    7882.       -7.     7886.      .16        0
  14     27    19660.      215.    -232.    19875.   19878.       -3.    19879.      .40        0
  15     23    -7523.     -116.     204.    -7639.       5.    -7645.     7647.      .15        0
  15     24   -11864.     -116.     204.   -11980.       3.   -11984.    11986.      .24        0
  16     24   -11882.     -120.     183.   -12001.       3.   -12004.    12005.      .24        0
  16     25   -17904.     -120.     183.   -18023.       2.   -18025.    18026.      .36        0
  17     25   -17902.     -121.     202.   -18023.       2.   -18026.    18027.      .36        0
  17     26   -10903.     -121.     202.   -11025.       4.   -11029.    11030.      .22        0
  18     26   -10883.     -122.     176.   -11005.       3.   -11008.    11009.      .22        0
  18     27    -9506.     -122.     176.    -9628.       3.    -9632.     9633.      .19        0
  19     23   -26348.   -23652.       8.   -50000.       0.   -50000.    50000.     1.00        1
  19     28    -4167.   -23652.       8.   -27819.       0.   -27819.    27819.      .56        0
  20     27   -28573.   -12532.      13.   -41105.       0.   -41105.    41105.      .82        0
  20     29    -4208.   -12532.      13.   -16740.       0.   -16740.    16740.      .33        0
```

TABLE 8. - Output listing, example structure 2--Continued

```
 MEMBER END REACTIONS-MEMBER COORDINATE SYSTEM (J LESS THAN K)
                                          J NODE                                                                   K NODE
MEMBER     X FORCE     Y FORCE     Z FORCE    X MOMENT    Y MOMENT    Z MOMENT     X FORCE     Y FORCE     Z FORCE    X MOMENT    Y MOMENT    Z MOMENT
   1        6673.1       654.1      -296.4        38.0      7656.5     33211.1     -6673.1      -654.1       296.4       -38.0     14572.2     15846.9
   2        6433.9       691.0       265.4        24.1     -6292.4     34180.2     -6433.9      -691.0      -265.4       -24.1    -13613.6     17647.0
   3         236.9      3347.4       -15.3       888.1        58.5     15141.1      -236.9     -3347.4        15.3      -888.1        94.9     18333.0
   4         234.7      1142.9         7.7       673.2       -95.0    -18376.0      -234.7     -1142.9        -7.7      -673.2        17.9     29805.2
   5         231.6     -1042.9        -7.8       339.9       -18.1    -29807.5      -231.6      1042.9         7.8      -339.9        95.6     19378.5
   6         226.3     -3246.0        13.2       110.4       -95.7    -19339.3      -226.3      3246.0       -13.2      -110.4       -36.3    -13121.2
   7        -411.6      2178.5        -3.7      -650.5       -20.5    -14964.3       411.6     -2178.5         3.7       650.5        57.2     36749.4
   8        -431.4      2043.8         -.7      -421.5        60.3    -17750.2       431.4     -2043.8          .7       421.5       -53.1     38188.7
   9        -365.1       -35.1         4.7      -591.7       -57.2    -36752.5       365.1        35.1        -4.7       591.7        10.5     36401.2
  10        -374.5      -168.4        -4.2      -492.8        53.1    -38187.3       374.5       168.4         4.2       492.8       -10.7     36503.1
  11        -371.9     -2227.3        -4.3      -420.0       -10.5    -36369.1       371.9      2227.3         4.3       420.0        53.4     14096.5
  12        -372.1     -2360.6         4.7      -662.1        10.7    -36465.6       372.1      2360.6        -4.7       662.1       -58.2     12859.6
  13        -432.5     -4437.3         -.8      -374.9       -53.5    -14026.1       432.5      4437.3          .8       374.9        61.1    -30346.9
  14        -423.5     -4572.1        -3.5      -689.2        58.2    -12784.5       423.5      4572.1         3.5       689.2       -22.8    -32937.0
  15         228.6      3236.9        13.4       604.5       -37.2     12575.4      -228.6     -3236.9       -13.4      -604.5       -96.7     19793.9
  16         235.4      1017.4        -7.8       541.5        96.6    -19823.2      -235.4     -1017.4         7.8      -541.5       -18.8     29997.2
  17         239.1     -1181.3         7.9       599.7        18.7    -29994.1      -239.1      1181.3        -7.9      -599.7       -98.1     18181.5
  18         240.4     -3402.3       -15.9       520.8        98.1    -18146.8      -240.4      3402.3        15.9      -520.8        61.2    -15876.4
  19       46564.0       414.8       267.3        24.0    -13060.4     31113.1    -46564.0      -414.8      -267.3       -24.0     -6986.3          .0
  20       24672.3       434.5      -298.2        38.2     15312.2     32591.1    -24672.3      -434.5       298.2       -38.2      7054.9          .0


                BUCKLING RESULTS


 BUCKLING       END      P.GT.15%    MEMBER        AXIAL
  MEMBER      MEMBERS   P CRITICAL   BUCKLE        STRESS      SIGMA1     SIGMA2      VMISES    VMISES/YIELD
    1          1   1        NO
    2         20  20        YES        NO          -12532.        0.     -54719.     54719.        1.09
* * CROSS SECTION HAS STARTED TO YIELD IN ABOVE BUCKLING MEMBER
    3         19  19        YES        YES,Z
```

TABLE 8. - Output listing, example structure 2--Continued

```
SHELL ELEMENT STRESSES

ELEMENT    MEMBRANE STRESS COMPONENTS      BENDING STRESS COMPONENTS           COMBINED STRESS COMPONENTS
NUMBER       SXX       SYY       SXY       MXX       MYY       MXY             XX         YY         XY

   1       102.3     -40.2      24.8    1617.1     660.6     612.6   (+)  -1514.8     -700.8      637.4
                                                                     (-)   1719.4      620.4     -587.8
   2        -4.2     -53.2      -4.3    2193.7    1705.8     266.7   (+)  -2197.9    -1759.0      262.4
                                                                     (-)   2189.5     1652.6     -271.0
   3        -4.7     -51.8        .4    2240.7    1739.1    -165.2   (+)  -2245.4    -1790.9     -164.8
                                                                     (-)   2236.0     1687.3      165.6
   4       107.8     -35.6     -31.5    1735.0     758.1    -527.5   (+)  -1627.2     -793.7     -559.0
                                                                     (-)   1842.7      722.6      495.9
   5       111.4      18.0      13.7    1993.1    1033.6     236.9   (+)  -1881.8    -1015.6      250.6
                                                                     (-)   2104.5     1051.5     -223.2
   6         9.5      33.9       1.0    1851.8    1367.9     155.0   (+)  -1842.3    -1334.0      156.0
                                                                     (-)   1861.3     1401.7     -154.1
   7        10.2      34.8      -7.7    1867.2    1376.1     -26.4   (+)  -1857.0    -1341.2      -34.1
                                                                     (-)   1877.3     1410.9       18.8
   8       114.5      19.0     -19.6    2033.3    1061.8    -131.0   (+)  -1918.8    -1042.8     -150.7
                                                                     (-)   2147.9     1080.9      111.4
   9       113.4      18.9     -21.1    1386.3     905.0    -201.1   (+)  -1272.9     -886.1     -222.3
                                                                     (-)   1499.7      924.0      180.0
  10         9.6      34.6      -8.5    1206.7    1190.3     -13.8   (+)  -1197.1    -1155.7      -22.2
                                                                     (-)   1216.3     1224.9        5.3
  11         9.9      34.0       1.6    1190.5    1167.1     144.8   (+)  -1180.6    -1133.1      146.4
                                                                     (-)   1200.4     1201.0     -143.2
  12       113.7      18.1      15.5    1342.9     836.2     308.3   (+)  -1229.3     -818.1      323.8
                                                                     (-)   1456.6      854.3     -292.8
  13       107.9     -36.1     -32.7    -251.5     222.6    -615.1   (+)    359.4     -258.7     -647.8
                                                                     (-)   -143.6      186.5      582.4
  14        -4.9     -52.9       -.3     221.3    1170.4    -168.8   (+)   -226.2    -1223.3     -169.1
                                                                     (-)    216.5     1117.5      168.5
  15        -4.2     -54.3      -4.3     171.1    1120.6     279.6   (+)   -175.3    -1174.9      275.4
                                                                     (-)    166.9     1066.4     -283.9
  16       105.4     -40.5      26.7    -376.2      78.6     707.1   (+)    481.6     -119.1      733.8
                                                                     (-)   -270.8       38.1     -680.4
```

TABLE 8. - Output listing, example structure 2--Continued

```
PRINCIPAL SHELL ELEMENT STRESSES

ELEMENT          COMBINED STRESS COMPONENTS          PRINCIPAL STRESS COMPONENTS       PRINCIPAL DIRECTION         VON MISES
NUMBER            XX          YY          XY            S1           S2                     THETA                  STRESS

   1    (+)    -1514.8      -700.8      637.4        -351.5      -1864.1                   -.5013                 1715.5
        (-)     1719.4       620.4     -587.8        1974.5        365.3                   -.4095                 1819.6
   2    (+)    -2197.9     -1759.0      262.4       -1636.4      -2320.5                   -.4371                 2065.2
        (-)     2189.5      1652.6     -271.0        2302.5       1539.6                   -.3951                 2031.5
   3    (+)    -2245.4     -1790.9     -164.8       -1737.4      -2298.9                    .3137                 2075.9
        (-)     2236.0      1687.3      165.6        2282.1       1641.2                    .2715                 2038.7
   4    (+)    -1627.2      -793.7     -559.0        -513.2      -1907.7                    .4651                 1709.9
        (-)     1842.7       722.6      495.9        2030.8        534.5                    .3624                 1823.2
   5    (+)    -1881.8     -1015.6      250.6        -948.3      -1949.1                   -.2623                 1688.1
        (-)     2104.5      1051.5     -223.2        2149.9       1006.2                   -.2005                 1863.1
   6    (+)    -1842.3     -1334.0      156.0       -1289.9      -1886.4                   -.2753                 1670.1
        (-)     1861.3      1401.7     -154.1        1908.2       1354.8                   -.2953                 1700.4
   7    (+)    -1857.0     -1341.2      -34.1       -1339.0      -1859.3                    .0657                 1661.4
        (-)     1877.3      1410.9       18.8        1878.1       1410.1                    .0402                 1693.3
   8    (+)    -1918.8     -1042.8     -150.7       -1017.6      -1944.0                    .1656                 1684.2
        (-)     2147.9      1080.9      111.4        2159.4       1069.4                    .1029                 1870.1
   9    (+)    -1272.9      -886.1     -222.3        -784.9      -1374.1                    .4274                 1194.0
        (-)     1499.7       924.0      180.0        1551.4        872.3                    .2794                 1347.0
  10    (+)    -1197.1     -1155.7      -22.2       -1146.0      -1206.7                    .4104                 1177.5
        (-)     1216.3      1224.9        5.3        1227.4       1213.8                   -.4467                 1220.7
  11    (+)    -1180.6     -1133.1      146.4       -1008.6      -1305.2                   -.7049                 1185.0
        (-)     1200.4      1201.0     -143.2        1343.9       1057.5                    .7842                 1226.0
  12    (+)    -1229.3      -818.1      323.8        -640.1      -1407.2                   -.5025                 1220.3
        (-)     1456.6       854.3     -292.8        1575.5        735.4                   -.3857                 1365.4
  13    (+)      359.4      -258.7     -647.8         768.0       -667.4                   -.5628                 1244.1
        (-)     -143.6       186.5      582.4         626.8       -583.9                   -.6474                 1048.8
  14    (+)     -226.2     -1223.3     -169.1        -198.3      -1251.2                   -.1635                 1164.7
        (-)      216.5      1117.5      168.5        1148.0        186.0                   -.1789                 1067.2
  15    (+)     -175.3     -1174.9      275.4        -104.4      -1245.7                    .2518                 1196.9
        (-)      166.9      1066.4     -283.9        1148.5         84.8                    .2816                 1108.5
  16    (+)      481.6      -119.1      733.8         974.1       -611.6                    .5911                 1385.2
        (-)     -270.8        38.1     -680.4         581.3       -814.1                    .6738                 1214.0
```

TABLE 8. - Output listing, example structure 2--Continued

```
INPUT LOADS,GLOBAL COORDINATE SYSTEM

   X DIRECTION:     200. POUNDS
   Y DIRECTION:   -7600. POUNDS
   Z DIRECTION:      0. POUNDS


MAXIMUM LOAD THAT CANOPY CAN SUPPORT IN X DIRECTION IS  -2195.  POUNDS
MAXIMUM LOAD THAT CANOPY CAN SUPPORT IN Y DIRECTION IS  84343.  POUNDS
MAXIMUM LOAD THAT CANOPY CAN SUPPORT IN Z DIRECTION IS     -0.  POUNDS

  WEIGHT OF BEAM ELEMENTS  = 257. POUNDS
  WEIGHT OF PLATE ELEMENTS = 113. POUNDS
  TOTAL CANOPY WEIGHT      = 370. POUNDS
```

Example 3. - Simple Plate Structure

The node and plate element numbering schemes are shown in figure 30. All plate elements are 5 by 5 inches, and 0.5 inch thick. Analysis is performed for two load cases, as shown in figures 31 and 32. The first load case, figure 30, represents a uniform inplane load in the X direction along the plate edge X = 20 inches to illustrate membrane action. Nodal load distribution is according to tributary areas; thus the midpoint load is twice as large as the outer point loads.

The second load case is a uniform load along X = 20 inches, perpendicular to plane of the plates, and illustrates bending action of the plate element.

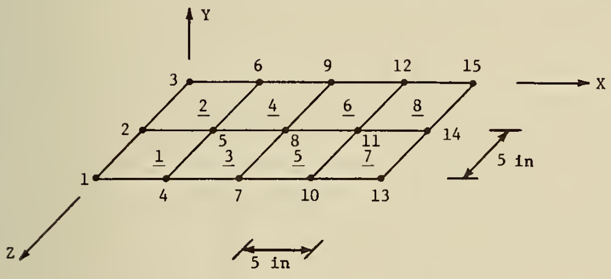


FIGURE 30. - Node and plate numbers, example 3.

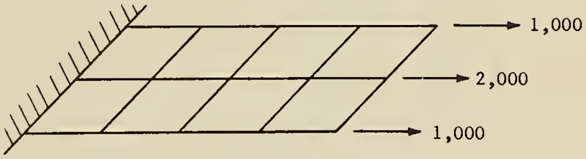


FIGURE 31. - Membrane load, example 3.

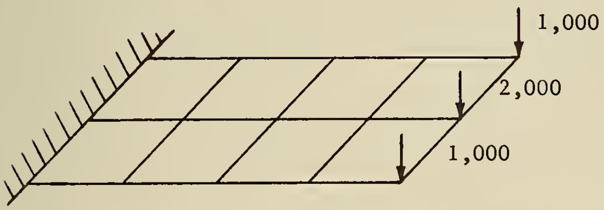


FIGURE 32. - Bending load, example 3.

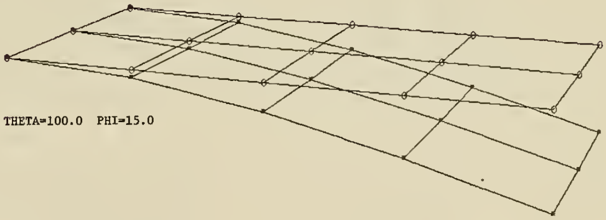


FIGURE 33. - Deformed and undeformed geometry plot for load case 2, example 3.

Input and output data are presented in tables 9 and 10; a deformed and undeformed plot of the second load case, for THETA = 100° and PHI = 30°, is shown in figure 33.

TABLE 9. - Input cards for example structure 3

```
     EXAMPLE STRUCTURE 3  PLASTIC CANOPY PROGRAM          MARCH 15,1978
    0
    2   15    3    0    0    0    8    3    2 28500000. 11090000.
    1   13    0.0       0.0      10.0      20.0       0.0      10.0         3
    2   14    0.0       0.0       5.0      20.0       0.0       5.0         3
    3   15    0.0       0.0       0.0      20.0       0.0       0.0         3
    1    1    4    5    2    1  0.5
    3    4    7    8    5    1  0.5
    5    7   10   11    8    1  0.5
    7   10   13   14   11    1  0.5
    8   11   14   15   12    1  0.5
    1    1    1    0    1    1    1
    2    1    1    1    1    1    1
    3    1    1    0    1    1    1
    2    0
   13   15    2 1000.0
   14   14    1 2000.0
    0                        1    1    1    0    1
    2    0
   13   15    2           -1000.0
   14   14    1           -2000.0
100.0 15.0
```

TABLE 10. - Output listing, example structure 3

```
                    -- P L A S T I C   C A N O P Y   R E S U L T S --

EXAMPLE STRUCTURE 3   PLASTIC CANOPY PROGRAM        MARCH 15,1978


  ** S T R U C T U R E   D A T A

     NUMBER OF JOINTS=  15

     NUMBER OF JT. DESIGNATION CARDS=   3

     NUMBER OF BEAM GEOMETRIES=   0

     NUMBER OF BEAM ELEMENTS=   0

     NUMBER OF BEAM ELEMENT OESIGNATION CARDS=   0

     NUMBER OF PLATE ELEMENTS=   8

     NUMBER OF RESTRAINED JOINTS=   3

     NUMBER OF LOADING CONDITIONS=   2

     NUMBER OF STRUCTURE GEOMETRIES=   2

     YOUNG S MODULUS FOR BEAMS= 28500000.

     SHEAR MOOULUS FOR BEAMS= 11090000.

     YOUNG S MOOULUS FOR PLATES= 28500000.

     POISSON RATIO FOR PLATES= .28


  ** P R O G R A M   O P T I O N S

     PLASTIC ANALYSIS:   NO

     PLOT UNOEFORMEO GEOMETRY:   NO

     PLOT OEFORMEO GEOMETRY:   NO

     NO. OF BUCKLING ELEMENTS:   0
```

TABLE 10. - Output listing, example structure 3--Continued

```
COORDINATES OF JOINTS
JOINT        X          Y         Z
   1        .00        .00      10.00
   2        .00        .00       5.00
   3        .00        .00        .00
   4       5.00        .00      10.00
   5       5.00        .00       5.00
   6       5.00        .00        .00
   7      10.00        .00      10.00
   8      10.00        .00       5.00
   9      10.00        .00        .00
  10      15.00        .00      10.00
  11      15.00        .00       5.00
  12      15.00        .00        .00
  13      20.00        .00      10.00
  14      20.00        .00       5.00
  15      20.00        .00        .00


THIN PLATE/SHELL ELEMENT DATA

ELEMENT                                                       NORMAL
 NUMBER   NODE-I   NODE-J   NODE-K   NODE-L   THICKNESS   PRESSURE

      1        1        4        5        2       .5000        .00
      2        2        5        6        3       .5000        .00
      3        4        7        8        5       .5000        .00
      4        5        8        9        6       .5000        .00
      5        7       10       11        8       .5000        .00
      6        8       11       12        9       .5000        .00
      7       10       13       14       11       .5000        .00
      8       11       14       15       12       .5000        .00


JOINT RESTRAINTS
     JOINT  X TRANS.  Y TRANS.  Z TRANS.   X ROTA.   Y ROTA.   Z ROTA.
       1         1         1         0         1         1         1
       2         1         1         1         1         1         1
       3         1         1         0         1         1         1


E Q U A T I O N   P A R A M E T E R S

 TOTAL NUMBER OF EQUATIONS =   90
 BANDWIDTH                 =   30
 NUMBER OF EQNS IN A BLOCK =   46
 NUMBER OF BLOCKS          =    2
```

TABLE 10. - Output listing, example structure 3--Continued

```
 LOADING NUMBER   1

 NO. OF LOADED JOINT CARDS  =  2
 NO. OF LOADED MEMBER CARDS =  0


ACTIONS APPLIED AT JOINTS
JOINT    X FORCE    Y FORCE    Z FORCE   X MOMENT   Y MOMENT   Z MOMENT
 13      1000.       0.         0.         0.         0.         0.
 15      1000.       0.         0.         0.         0.         0.
 14      2000.       0.         0.         0.         0.         0.


 REACTIONS AT RESTRAINED JOINTS
 JOINT   X FORCE        Y FORCE        Z FORCE       X MOMENT       Y MOMENT       Z MOMENT
   1     -1000.0             .0             .0             .0             .0             .0
   2     -2000.0             .0             .0             .0             .0             .0
   3     -1000.0             .0             .0             .0             .0             .0


 SHELL ELEMENT STRESSES

ELEMENT    MEMBRANE STRESS COMPONENTS      BENDING STRESS COMPONENTS          COMBINED STRESS COMPONENTS
 NUMBER        SXX        SYY        SXY        MXX        MYY        MXY            XX         YY         XY

      1      800.0         .0         .0         .0         .0         .0   (+)    800.0         .0         .0
                                                                               (-)    800.0         .0         .0
      2      800.0         .0         .0         .0         .0         .0   (+)    800.0         .0         .0
                                                                               (-)    800.0         .0         .0
      3      800.0        -.0        -.0         .0         .0         .0   (+)    800.0        -.0        -.0
                                                                               (-)    800.0        -.0        -.0
      4      800.0        -.0         .0         .0         .0         .0   (+)    800.0        -.0         .0
                                                                               (-)    800.0        -.0         .0
      5      800.0        -.0        -.0         .0         .0         .0   (+)    800.0        -.0        -.0
                                                                               (-)    800.0        -.0        -.0
      6      800.0        -.0         .0         .0         .0         .0   (+)    800.0        -.0         .0
                                                                               (-)    800.0        -.0         .0
      7      800.0        -.0        -.0         .0         .0         .0   (+)    800.0        -.0        -.0
                                                                               (-)    800.0        -.0        -.0
      8      800.0        -.0         .0         .0         .0         .0   (+)    800.0        -.0         .0
                                                                               (-)    800.0        -.0         .0
```

TABLE 10. - Output listing, example structure 3--Continued

```
PRINCIPAL SHELL ELEMENT STRESSES

ELEMENT       COMBINED STRESS COMPONENTS         PRINCIPAL STRESS COMPONENTS      PRINCIPAL DIRECTION        VON MISES
NUMBER         XX          YY          XY             S1            S2                   THETA               STRESS

   1    (+)   800.0        .0          .0           800.0          .0                   .0000                800.0
        (-)   800.0        .0          .0           800.0          .0                   .0000                800.0
   2    (+)   800.0        .0          .0           800.0          .0                   .0000                800.0
        (-)   800.0        .0          .0           800.0          .0                   .0000                800.0
   3    (+)   800.0       -.0         -.0           800.0         -.0                  -.0000                800.0
        (-)   800.0       -.0         -.0           800.0         -.0                  -.0000                800.0
   4    (+)   800.0       -.0          .0           800.0         -.0                   .0000                800.0
        (-)   800.0       -.0          .0           800.0         -.0                   .0000                800.0
   5    (+)   800.0       -.0         -.0           800.0         -.0                  -.0000                800.0
        (-)   800.0       -.0         -.0           800.0         -.0                  -.0000                800.0
   6    (+)   800.0       -.0          .0           800.0         -.0                   .0000                800.0
        (-)   800.0       -.0          .0           800.0         -.0                   .0000                800.0
   7    (+)   800.0       -.0         -.0           800.0          .0                  -.0000                800.0
        (-)   800.0       -.0         -.0           800.0          .0                  -.0000                800.0
   8    (+)   800.0       -.0          .0           800.0          .0                   .0000                800.0
        (-)   800.0       -.0          .0           800.0          .0                   .0000                800.0


  INPUT LOADS,GLOBAL COORDINATE SYSTEM

    X DIRECTION:    4000. POUNDS
    Y DIRECTION:       0. POUNDS
    Z DIRECTION:       0. POUNDS


MAXIMUM LOAD THAT CANOPY CAN SUPPORT IN X DIRECTION IS  -4000.  POUNDS
MAXIMUM LOAD THAT CANOPY CAN SUPPORT IN Y DIRECTION IS      0.  POUNDS
MAXIMUM LOAD THAT CANOPY CAN SUPPORT IN Z DIRECTION IS      0.  POUNDS

 WEIGHT OF BEAM ELEMENTS  =   0. POUNDS
 WEIGHT OF PLATE ELEMENTS =  28. POUNDS
 TOTAL CANOPY WEIGHT      =  28. POUNDS


      ** P R O G R A M   O P T I O N S

         PLASTIC ANALYSIS:   NO

         PLOT UNDEFORMED GEOMETRY:  YES

         PLOT DEFORMED GEOMETRY:  YES

         NO. OF BUCKLING ELEMENTS:   0
```

TABLE 10. - Output listing, example structure 3--Continued

```
 LOADING NUMBER  2

 NO. OF LOADED JOINT CARDS  =  2
 NO. OF LOADED MEMBER CARDS =  0


ACTIONS APPLIED AT JOINTS
JOINT    X FORCE    Y FORCE    Z FORCE   X MOMENT   Y MOMENT   Z MOMENT
 13         0.       -1000.        0.         0.         0.         0.
 15         0.       -1000.        0.         0.         0.         0.
 14         0.       -2000.        0.         0.         0.         0.


 REACTIONS AT RESTRAINED JOINTS
 JOINT   X FORCE      Y FORCE      Z FORCE     X MOMENT     Y MOMENT     Z MOMENT
   1          .0       -488.4           .0       5877.0           .0      17337.7
   2          .0       4976.4           .0          -.0           .0      45315.7
   3          .0       -488.3           .0      -5877.1           .0      17338.1


  SHELL ELEMENT STRESSES

 ELEMENT    MEMBRANE STRESS COMPONENTS      BENDING STRESS COMPONENTS            COMBINED STRESS COMPONENTS
  NUMBER       SXX        SYY        SXY        MXX        MYY        MXY                XX         YY         XY

     1          .0         .0         .0 -167981.4   -36775.8    -9895.4    (+)   167981.4    36775.8    -9895.4
                                                                            (-)  -167981.4   -36775.8     9895.4
     2          .0         .0         .0 -167982.1   -36776.0     9894.5    (+)   167982.1    36776.0     9894.5
                                                                            (-)  -167982.1   -36776.0    -9894.5
     3          .0         .0         .0 -119986.4   -11718.9    -1725.2    (+)   119986.4    11718.9    -1725.2
                                                                            (-)  -119986.4   -11718.9     1725.2
     4          .0         .0         .0 -119986.3   -11718.9     1724.2    (+)   119986.3    11718.9     1724.2
                                                                            (-)  -119986.3   -11718.9    -1724.2
     5          .0         .0         .0  -71992.0    -1767.2     2254.0    (+)    71992.0     1767.2     2254.0
                                                                            (-)   -71992.0    -1767.2    -2254.0
     6          .0         .0         .0  -71991.8    -1767.2    -2254.9    (+)    71991.8     1767.2    -2254.9
                                                                            (-)   -71991.8    -1767.2     2254.9
     7          .0         .0         .0  -23997.5     4193.7     1776.4    (+)    23997.5    -4193.7     1776.4
                                                                            (-)   -23997.5     4193.7    -1776.4
     8          .0         .0         .0  -23997.6     4193.6    -1777.0    (+)    23997.6    -4193.6    -1777.0
                                                                            (-)   -23997.6     4193.6     1777.0
```

TABLE 10. - Output listing, example structure 3--Continued

```
 PRINCIPAL SHELL ELEMENT STRESSES

ELEMENT        COMBINED STRESS COMPONENTS        PRINCIPAL STRESS COMPONENTS      PRINCIPAL DIRECTION        VON MISES
NUMBER            XX         YY         XY           S1           S2                  THETA                 STRESS

   1    (+)   167981.4    36775.8    -9895.4      168723.5      36033.7               -.0749                153903.6
        (-)  -167981.4   -36775.8     9895.4      -36033.7    -168723.5               -.0749                153903.6
   2    (+)   167982.1    36776.0     9894.5      168724.1      36034.0                .0748                153904.0
        (-)  -167982.1   -36776.0    -9894.5      -36034.0    -168724.1                .0748                153904.0
   3    (+)   119986.4    11718.9    -1725.2      120013.9      11691.4               -.0159                114616.3
        (-)  -119986.4   -11718.9     1725.2      -11691.4    -120013.9               -.0159                114616.3
   4    (+)   119986.3    11718.9     1724.2      120013.8      11691.5                .0159                114616.1
        (-)  -119986.3   -11718.9    -1724.2      -11691.5    -120013.8                .0159                114616.1
   5    (+)    71992.0     1767.2     2254.0       72064.2       1694.9                .0321                 71231.9
        (-)   -71992.0    -1767.2    -2254.0       -1694.9     -72064.2                .0321                 71231.9
   6    (+)    71991.8     1767.2    -2254.9       72064.1       1694.9               -.0321                 71231.8
        (-)   -71991.8    -1767.2     2254.9       -1694.9     -72064.1               -.0321                 71231.8
   7    (+)    23997.5    -4193.7     1776.4       24109.0      -4305.2                .0627                 26524.9
        (-)   -23997.5     4193.7    -1776.4        4305.2     -24109.0                .0627                 26524.9
   8    (+)    23997.6    -4193.6    -1777.0       24109.2      -4305.2               -.0627                 26525.1
        (-)   -23997.6     4193.6     1777.0        4305.2     -24109.2               -.0627                 26525.1

* * * PLATE STRESS WARNING-SOME ELEMENTS ARE STRESSED
      ABOVE 36000 PSI. SEE COLUMN OF VON MISES STRESS
      COMPONENTS.


 INPUT LOADS,GLOBAL COORDINATE SYSTEM

   X DIRECTION:      0. POUNDS
   Y DIRECTION:  -4000. POUNDS
   Z DIRECTION:      0. POUNDS


MAXIMUM LOAD THAT CANOPY CAN SUPPORT IN X DIRECTION IS      0.   POUNDS
MAXIMUM LOAD THAT CANOPY CAN SUPPORT IN Y DIRECTION IS   4000.   POUNDS
MAXIMUM LOAD THAT CANOPY CAN SUPPORT IN Z DIRECTION IS      0.   POUNDS

 WEIGHT OF BEAM ELEMENTS  =   0. POUNDS
 WEIGHT OF PLATE ELEMENTS =  28. POUNDS
 TOTAL CANOPY WEIGHT      =  28. POUNDS
```

Example 4. - Underground Mining Vehicle Canopy

A model of an underground mining vehicle roof canopy is shown in figure 34, with nodal numbering and plate element numbering shown. The model is only one-half of the real structure, where an axis of symmetry along the X-axis enables substructuring to be used. Nodal points along the centerline, nodes 6, 10, 13, 16, 19, 22, 26, 30, 32, 43, 45, 47, 50, 53, 56, and 59, have boundary conditions preventing displacement in the Z-direction and rotation about the X-direction; all other displacements along the centerline are free to occur.

A vertical loading is applied, with the following forces acting on the given nodes:

Joints 25, 26, 30, 31: $F_y = 2{,}000.0$

Joint 29: $F_y = 4{,}000.0$

Joint 32: $F_y = 1{,}000.0$

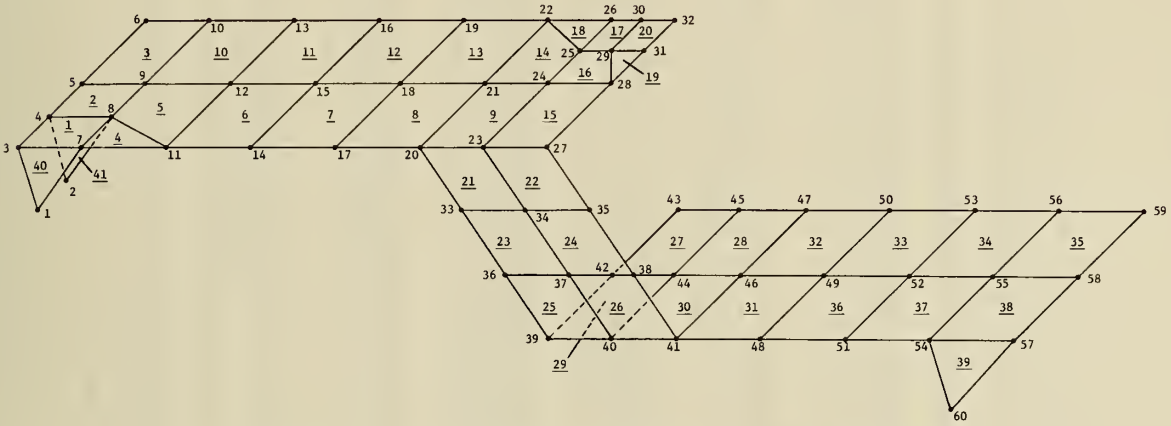


FIGURE 34. - Nodal numbers and plate numbers, example 4.

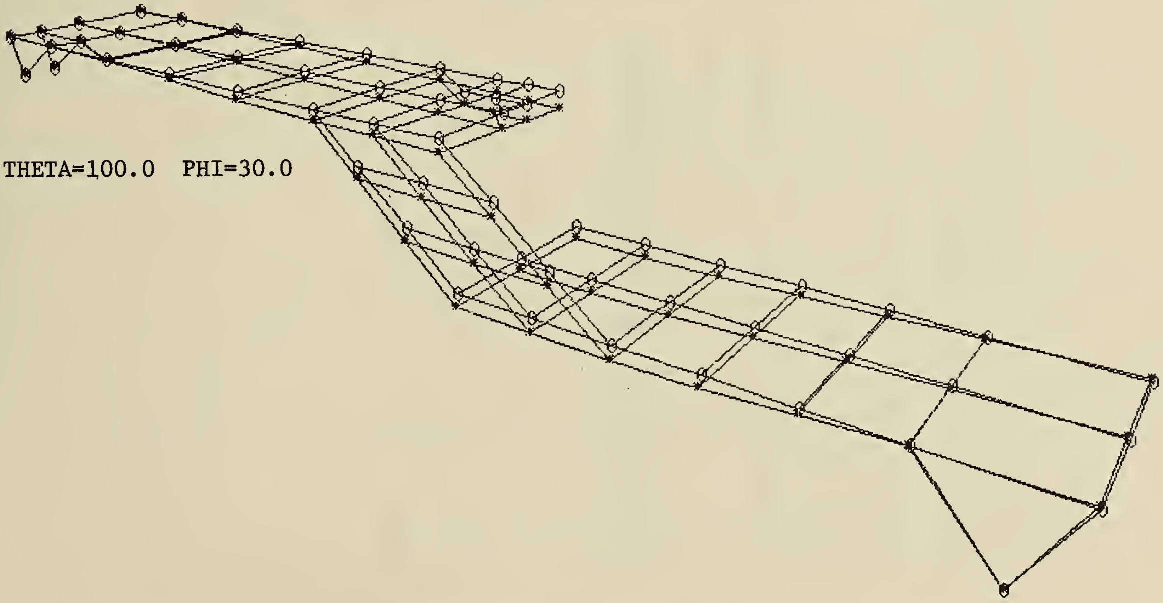


FIGURE 35. - Deformed and undeformed geometry plot, example 4.

Input and output data for this example are shown in tables 11 and 12. Figure 35 is a deformed and undeformed geometry plot, with a deflection magnification factor of DMAG = 3.0 and orientation angles THETA = 100°, PHI = 30°.

TABLE 11. - Input cards for example structure 4

```
      EXAMPLE STRUCTURE 4   PLASTIC CANOPY PROGRAM        MARCH 15,1978
    0
                             1    1
    1   63   27    0    0    0   41   19    1    0.0       0.0    30000000.  .28
    1    2    1.5       5.25     10.125     1.5       5.25      8.0       1
    3    4    0.0       7.75     10.125     0.0       7.75      8.0       1
    5    6    0.0       7.75      5.0675    0.0       7.75      0.0       1
    7    8    4.375     7.75     10.125     4.375     7.75      8.0       1
    9   10    4.375     7.75      5.0675    4.375     7.75      0.0       1
   11   13    9.9688    7.75     10.125     9.9688    7.75      0.0       1
   14   16   15.563     7.75     10.125    15.563     7.75      0.0       1
   17   19   21.156     7.75     10.156    21.156     7.75      0.0       1
   20   22   26.75      7.75     10.125    26.75      7.75      0.0       1
   23   24   30.75      7.75     10.125    30.75      7.75      5.0675    1
   25   26   30.75      7.75      3.0      30.75      7.75      0.0       1
   27   28   34.75      7.75     10.125    34.75      7.75      5.0675    1
   29   30   32.75      7.75      3.0      32.75      7.75      0.0       1
   31   32   34.75      7.75      3.0      34.75      7.75      0.0       1
   33   35   29.75      5.1667   10.125    37.75      5.1667   10.125     1
   36   38   32.75      2.583    10.125    40.75      2.583    10.125     1
   39   41   35.75      0.0      10.125    43.75      0.0      10.125     1
   42   43   35.75      0.0       5.0675   35.75      0.0       0.0       1
   44   45   39.75      0.0       5.0675   39.75      0.0       0.0       1
   46   47   43.75      0.0       5.0675   43.75      0.0       0.0       1
   48   50   47.75      0.0      10.125    47.75      0.0       0.0       1
   51   53   51.75      0.0      10.125    51.75      0.0       0.0       1
   54   56   55.75      0.0      10.125    55.75      0.0       0.0       1
   57   59   61.75      0.0      10.125    61.75      0.0       0.0       1
   60   60                                 58.75     -4.375    10.125     1
    1    3    7    8    4    1    1.0
    4    7   11    8    0    1    1.0
    5    8   11   12    9    3    1.0
   10    9   12   13   10    3    1.0
   15   23   27   28   24    1    1.0
   18   22   25   26    0    1    1.0
   19   29   28   31    0    1    1.0
   20   29   31   32   30    1    1.0
   21   33   34   23   20    1    1.0
   22   34   35   27   23    1    1.0
   23   36   37   34   33    1    1.0
   25   39   40   37   36    1    1.0
   27   42   44   45   43    2    1.0
   29   39   40   44   42    1    1.0
   30   40   41   46   44    1    1.0
   31   41   48   49   46    1    1.0
   32   46   49   50   47    1    1.0
   33   49   52   53   50    3    1.0
```

TABLE 11. - Input cards for example structure 4--Continued

36	48	51	52	49	3	1.0									
38	54	57	58	55	1	1.0									
39	60	63	57	54	1	0.75									
40	1	61	7	3	1	0.75									
41	2	62	8	4	1	0.75									
2	1	1	1												
1	1	1	1												
6	0	0	1	1	1										
10	0	0	1	1	1										
13	0	0	1	1	1										
16	0	0	1	1	1										
19	0	0	1	1	1										
22	0	0	1	1	1										
26	0	0	1	1	1										
30	0	0	1	1	1										
32	0	0	1	1	1										
43	0	0	1	1	1										
45	0	0	1	1	1										
47	0	0	1	1	1										
50	0	0	1	1	1										
53	0	0	1	1	1										
56	0	0	1	1	1										
59	0	0	1	1	1										
60	1	1	1	1	1										
6	0														
25	25	1	0.0		-1000.0										
26	26	1	0.0		-2000.0										
29	29	1	0.0		-2000.0										
30	30	1	0.0		-4000.0										
31	31	1	0.0		-2000.0										
32	32	1	0.0		-2000.0										

TABLE 12. - Output listing, example structure 4

```
                  - -  P L A S T I C   C A N O P Y   R E S U L T S  - -

EXAMPLE STRUCTURE 4   PLASTIC CANOPY PROGRAM         MARCH 15,1978


    • •  S T R U C T U R E   D A T A

         NUMBER OF JOINTS=  60

         NUMBER OF JT. DESIGNATION CARDS=  25

         NUMBER OF BEAM GEOMETRIES=   0

         NUMBER OF BEAM ELEMENTS=   0

         NUMBER OF BEAM ELEMENT DESIGNATION CARDS=   0

         NUMBER OF PLATE ELEMENTS=  41

         NUMBER OF RESTRAINED JOINTS=  19

         NUMBER OF LOADING CONDITIONS=   1

         NUMBER OF STRUCTURE GEOMETRIES=   1

         YOUNG S MODULUS FOR BEAMS= 28500000.

         SHEAR MODULUS FOR BEAMS= 11090000.

         YOUNG S MODULUS FOR PLATES= 30000000.

         POISSON RATIO FOR PLATES= .28


    • •  P R O G R A M   O P T I O N S

         PLASTIC ANALYSIS:   NO

         PLOT UNDEFORMED GEOMETRY:  YES

         PLOT DEFORMED GEOMETRY:  YES

         NO. OF BUCKLING ELEMENTS:   0
```

TABLE 12. - Output listing, example structure 4--Continued

```
COORDINATES OF JOINTS
JOINT       X          Y          Z
    1     1.50       5.25      10.12
    2     1.50       5.25       8.00
    3      .00       7.75      10.12
    4      .00       7.75       8.00
    5      .00       7.75       5.07
    6      .00       7.75        .00
    7     4.38       7.75      10.12
    8     4.38       7.75       8.00
    9     4.38       7.75       5.07
   10     4.38       7.75        .00
   11     9.97       7.75      10.12
   12     9.97       7.75       5.06
   13     9.97       7.75        .00
   14    15.56       7.75      10.12
   15    15.56       7.75       5.06
   16    15.56       7.75        .00
   17    21.16       7.75      10.12
   18    21.16       7.75       5.06
   19    21.16       7.75        .00
   20    26.75       7.75      10.12
   21    26.75       7.75       5.06
   22    26.75       7.75        .00
   23    30.75       7.75      10.12
   24    30.75       7.75       5.07
   25    30.75       7.75       3.00
   26    30.75       7.75        .00
   27    34.75       7.75      10.12
   28    34.75       7.75       5.07
   29    32.75       7.75       3.00
   30    32.75       7.75        .00
   31    34.75       7.75       3.00
   32    34.75       7.75        .00
   33    29.75       5.17      10.12
   34    33.75       5.17      10.12
   35    37.75       5.17      10.12
   36    32.75       2.58      10.12
   37    36.75       2.58      10.12
   38    40.75       2.58      10.12
   39    35.75        .00      10.12
   40    39.75        .00      10.12
   41    43.75        .00      10.12
   42    35.75        .00       5.07
   43    35.75        .00        .00
   44    39.75        .00       5.07
   45    39.75        .00        .00
   46    43.75        .00       5.07
   47    43.75        .00        .00
   48    47.75        .00      10.12
   49    47.75        .00       5.06
   50    47.75        .00        .00
```

TABLE 12. - Output listing, example structure 4--Continued

```
COORDINATES OF JOINTS
JOINT        X          Y          Z
  51      51.75        .00      10.12
  52      51.75        .00       5.06
  53      51.75        .00        .00
  54      55.75        .00      10.12
  55      55.75        .00       5.06
  56      55.75        .00        .00
  57      61.75        .00      10.12
  58      61.75        .00       5.06
  59      61.75        .00        .00
  60      58.75      -4.38      10.12
```

TABLE 12. - Output listing, example structure 4--Continued

```
THIN PLATE/SHELL ELEMENT DATA

ELEMENT                                                        NORMAL
 NUMBER   NODE-I   NODE-J   NODE-K   NODE-L   THICKNESS   PRESSURE

      1        3        7        8        4      1.0000        .00
      2        4        8        9        5      1.0000        .00
      3        5        9       10        6      1.0000        .00
      4        7       11        8        0      1.0000        .00
      5        8       11       12        9      1.0000        .00
      6       11       14       15       12      1.0000        .00
      7       14       17       18       15      1.0000        .00
      8       17       20       21       18      1.0000        .00
      9       20       23       24       21      1.0000        .00
     10        9       12       13       10      1.0000        .00
     11       12       15       16       13      1.0000        .00
     12       15       18       19       16      1.0000        .00
     13       18       21       22       19      1.0000        .00
     14       21       24       25       22      1.0000        .00
     15       23       27       28       24      1.0000        .00
     16       24       28       29       25      1.0000        .00
     17       25       29       30       26      1.0000        .00
     18       22       25       26        0      1.0000        .00
     19       29       28       31        0      1.0000        .00
     20       29       31       32       30      1.0000        .00
     21       33       34       23       20      1.0000        .00
     22       34       35       27       23      1.0000        .00
     23       36       37       34       33      1.0000        .00
     24       37       38       35       34      1.0000        .00
     25       39       40       37       36      1.0000        .00
     26       40       41       38       37      1.0000        .00
     27       42       44       45       43      1.0000        .00
     28       44       46       47       45      1.0000        .00
     29       39       40       44       42      1.0000        .00
     30       40       41       46       44      1.0000        .00
     31       41       48       49       46      1.0000        .00
     32       46       49       50       47      1.0000        .00
     33       49       52       53       50      1.0000        .00
     34       52       55       56       53      1.0000        .00
     35       55       58       59       56      1.0000        .00
     36       48       51       52       49      1.0000        .00
     37       51       54       55       52      1.0000        .00
     38       54       57       58       55      1.0000        .00
     39       60       57       54        0       .7500        .00
     40        1        7        3        0       .7500        .00
     41        2        8        4        0       .7500        .00
```

TABLE 12. - Output listing, example structure 4--Continued

```
JOINT RESTRAINTS
    JOINT   X TRANS.  Y TRANS.  Z TRANS.   X ROTA.   Y ROTA.   Z ROTA.
      1         1         1         1         0         0         0
      2         1         1         1         0         0         0
      6         0         0         1         1         1         0
     10         0         0         1         1         1         0
     13         0         0         1         1         1         0
     16         0         0         1         1         1         0
     19         0         0         1         1         1         0
     22         0         0         1         1         1         0
     26         0         0         1         1         1         0
     30         0         0         1         1         1         0
     32         0         0         1         1         1         0
     43         0         0         1         1         1         0
     45         0         0         1         1         1         0
     47         0         0         1         1         1         0
     50         0         0         1         1         1         0
     53         0         0         1         1         1         0
     56         0         0         1         1         1         0
     59         0         0         1         1         1         0
     60         1         1         1         0         0         0


  E Q U A T I O N   P A R A M E T E R S

   TOTAL NUMBER OF EQUATIONS =  360
   BANDWIDTH                 =   90
   NUMBER OF EQNS IN A BLOCK =   16
   NUMBER OF BLOCKS          =   23


  LOADING NUMBER  1

  NO. OF LOAOEO JOINT CARDS  =  6
  NO. OF LOADEO MEMBER CARDS =  0

ACTIONS APPLIED AT JOINTS
JOINT    X FORCE    Y FORCE    Z FORCE   X MOMENT   Y MOMENT   Z MOMENT
  25        0.       -1000.       0.         0.         0.         0.
  26        0.       -2000.       0.         0.         0.         0.
  29        0.       -2000.       0.         0.         0.         0.
  30        0.       -4000.       0.         0.         0.         0.
  31        0.       -2000.       0.         0.         0.         0.
  32        0.       -2000.       0.         0.         0.         0.
```

TABLE 12. - Output listing, example structure 4--Continued

```
REACTIONS AT RESTRAINED JOINTS
JOINT  X FORCE    Y FORCE    Z FORCE   X MOMENT   Y MOMENT   Z MOMENT
    1   1434.0    -1807.9     -480.2         .0         .0         .0
    2  16738.7     4607.5      -91.0         .0         .0         .0
    6       .0         .0    -3466.1    -2848.8         .0         .0
   10       .0         .0     -448.8      857.2         .0         .0
   13       .0         .0     2586.3     1799.2         .0         .0
   16       .0         .0     2698.2     2395.2         .0         .0
   19       .0         .0     3523.3     5462.1         .0         .0
   22       .0         .0     3613.3    14005.0         .0         .0
   26       .0         .0      326.3    18175.1         .0         .0
   30       .0         .0    -1729.1    18211.9         .0         .0
   32       .0         .0    -1873.2    11756.9         .0         .0
   43       .0         .0    -6301.6     1912.1         .0         .0
   45       .0         .0    -5276.7    -2635.2         .0         .0
   47       .0         .0     1327.3    -5189.0         .0         .0
   50       .0         .0     5257.2    -3467.1         .0         .0
   53       .0         .0     5285.2     1357.8         .0         .0
   56       .0         .0      885.4     3987.0         .0         .0
   59       .0         .0    -4713.9    -1479.9         .0         .0
   60 -18177.2    10166.9    -1121.4         .0         .0         .0
```

TABLE 12. - Output listing, example structure 4--Continued

```
SHELL ELEMENT STRESSES

ELEMENT    MEMBRANE STRESS COMPONENTS       BENDING STRESS COMPONENTS             COMBINED STRESS COMPONENTS
NUMBER          SXX        SYY        SXY        MXX        MYY        MXY                XX         YY         XY

       1    -1587.7     -107.2      487.3   -15051.4    -1137.8    -4857.9  (+)    13463.6     1030.7    -4370.6
                                                                            (-)   -16639.1    -1245.0     5345.3
       2    -1244.4      246.6    -1208.4   -12697.9    -2404.1    -8041.0  (+)    11453.5     2650.7    -9249.4
                                                                            (-)   -13942.4    -2157.4     6832.7
       3     -305.9      809.2     -263.1    -8471.4    -2351.7    -3425.7  (+)     8165.5     3161.0    -3688.8
                                                                            (-)    -8777.3    -1542.5     3162.5
       4    -2690.5     -235.2      897.1   -29400.6   -14641.2     2863.0  (+)    26710.2    14406.0     3760.1
                                                                            (-)   -32091.1   -14876.4    -1965.9
       5    -2069.4     -384.6    -1064.0   -18637.1    -4667.1    -2631.1  (+)    16567.8     4282.5    -3695.1
                                                                            (-)   -20706.5    -5051.8     1567.1
       6    -2002.1      -99.7     -206.9    -8448.9       -2.9      487.5  (+)     6446.8      -96.8      280.6
                                                                            (-)   -10451.0     -102.5     -694.4
       7    -1928.5     -152.2       90.2     1776.8     1312.6     -399.7  (+)    -3705.3    -1464.8     -309.5
                                                                            (-)     -151.7     1160.3      489.8
       8    -2265.4     -161.8      514.1    12562.1     2249.7    -2626.2  (+)   -19827.5    -2411.5    -2112.2
                                                                            (-)    10296.8     2088.0     3140.3
       9    -2707.3     -462.7     1326.5     8869.6    -2107.1   -14144.0  (+)   -11576.9     1644.4   -12817.6
                                                                            (-)     6162.3    -2569.8    15470.5
      10    -1075.1     -246.9     -363.7   -15253.0     -418.4      -97.5  (+)    14178.0      171.5     -461.2
                                                                            (-)   -16328.1     -665.3     -266.2
      11    -1587.7     -405.9     -168.3    -8016.5     1501.9      187.0  (+)     6428.9    -1907.8       18.7
                                                                            (-)    -9604.2     1095.9     -355.4
      12    -1661.2     -437.4       67.6      316.2     3821.0     -558.0  (+)    -1977.4    -4258.4     -490.5
                                                                            (-)    -1345.0     3383.5      625.6
      13    -1324.4     -641.7      339.6     8089.0    10121.7    -2911.7  (+)    -9413.4   -10763.4    -2572.1
                                                                            (-)     6764.7     9480.0     3251.4
      14     -950.3     -303.6      514.0    15756.8     8740.3    -9175.7  (+)   -16707.1    -9043.9    -8661.8
                                                                            (-)    14806.5     8436.7     9689.7
      15    -2549.4     -303.4     1147.4    -1143.9   -13240.4   -13577.6  (+)    -1405.5    12937.1   -12430.2
                                                                            (-)    -3693.2   -13543.8    14724.9
      16      244.6      330.9       -3.2     5622.4    20980.5   -10973.3  (+)    -5377.8   -20649.7   -10976.5
                                                                            (-)     5867.0    21311.4    10970.2
      17       40.1      308.6        4.7    10441.1    35972.4    -4074.0  (+)   -10401.0   -35663.8    -4069.3
                                                                            (-)    10481.1    36280.9     4078.6
      18     -595.8     -139.9      223.4    17234.1    33045.5   -10241.5  (+)   -17829.9   -33185.4   -10018.1
                                                                            (-)    16638.3    32905.6    10464.8
      19      533.8     1563.5     -814.6    16662.4    14225.2   -23646.7  (+)   -16128.6   -12661.7   -24461.3
                                                                            (-)    17196.2    15788.8    22832.2
      20      -12.7     1433.8      -28.3     6493.0    44157.9    -6559.1  (+)    -6505.7   -42724.1    -6587.4
                                                                            (-)     6480.2    45591.7     6530.8
      21    -1410.6      351.1     -774.8    -8379.1   -13400.2     1607.2  (+)     6968.5    13751.3      832.4
                                                                            (-)    -9789.7   -13049.1    -2382.0
      22    -6203.7    -2898.2     5318.3    -6009.3   -29340.9     3790.2  (+)     -194.4    26442.8     9108.5
                                                                            (-)   -12213.0   -32239.1     1528.1
      23     1147.4     1249.7     -959.2    -3386.0   -14539.1     5767.6  (+)     4533.4    15788.8     4808.4
                                                                            (-)    -2238.5   -13289.4    -6726.8
      24    -8600.9    -3793.8     5502.8     6517.2   -11819.3     2762.7  (+)   -15118.1     8025.5     8265.4
                                                                            (-)    -2083.7   -15613.2     2740.1
      25     1947.9      432.6    -2741.1     9188.5    -2954.9      809.0  (+)    -7240.6     3387.5    -1932.2
```

TABLE 12. - Output listing, example structure 4--Continued

```
                                                                (-)   11136.4   -2522.3   -3550.1
26   -6325.8   -2975.8    7284.7    2419.7   -6513.8    7986.4  (+)   -8745.6    3538.0   15271.1
                                                                (-)   -3906.1   -9489.6    -701.7
27    -205.3    2363.7     -67.0    5745.1   -1466.4    3275.7  (+)   -5950.5    3830.1    3208.6
                                                                (-)    5539.8     897.3   -3342.7
28    -162.4     426.3     -18.0   19620.8   -3718.9    2815.2  (+)  -19783.2    4145.2    2797.2
                                                                (-)   19458.4   -3292.7   -2833.2
29    1614.8    2066.0      68.6     136.0   -5331.2    6526.3  (+)    1478.9    7397.2    6594.9
                                                                (-)    1750.8   -3265.2   -6457.7
30    -928.9     -31.3   -1353.8   29529.8    -482.6   14974.9  (+)  -30458.7     451.3   13621.2
                                                                (-)   28600.9    -513.9  -16328.7
31   -3141.7    -579.6    -932.4   40359.7    1068.3  -10814.4  (+)  -43501.4   -1647.9  -11746.9
                                                                (-)   37218.0     488.7    9882.0
32    -451.3    -894.9    -171.4   22040.8   -3980.5   -2180.2  (+)  -22492.0    3085.6   -2351.5
                                                                (-)   21589.5   -4875.4    2008.8
33    -777.2   -1314.8     -19.4    6793.8   -1316.8   -4477.5  (+)   -7571.0       2.0   -4496.9
                                                                (-)    6016.6   -2631.6    4458.0
34    -515.4    -902.2     140.5   -9264.8    1835.3   -2391.1  (+)    8749.4   -2737.5   -2250.5
                                                                (-)   -9780.2     933.0    2531.6
35    -241.2     804.2      89.9  -10055.9     252.0    2818.0  (+)    9814.8     552.3    2907.9
                                                                (-)  -10297.1    1056.2   -2728.1
36   -2813.2    -518.2     -46.8    7403.6    -489.7  -13912.9  (+)  -10216.8     -28.5  -13959.7
                                                                (-)    4590.4   -1007.9   13866.1
37   -3075.0    -634.3     837.2  -24739.4   -1360.9  -10561.7  (+)   21664.4     726.7   -9724.4
                                                                (-)  -27814.4   -1995.2   11398.9
38    -784.5     388.1     952.0  -18995.9   -1096.1   13917.8  (+)   18211.5    1484.3   14869.9
                                                                (-)  -19780.4    -708.0  -12965.8
39   -4518.6   -2374.8   -8078.8  -20750.7    3329.3   -8814.0  (+)   16232.1   -5704.1  -16892.8
                                                                (-)  -25269.3     954.5     735.3
40     517.2    -273.9    1252.4    -184.2    4883.9    2040.1  (+)     701.4   -5157.8    3292.6
                                                                (-)     333.0    4610.0    -787.7
41   -8020.1    2477.2    8749.1    5044.3    5994.4    5116.0  (+)  -13064.5   -3517.3   13865.1
                                                                (-)   -2975.8    8471.6    3633.1
```

TABLE 12. - Output listing, example structure 4--Continued

```
PRINCIPAL SHELL ELEMENT STRESSES

ELEMENT          COMBINED STRESS COMPONENTS        PRINCIPAL STRESS COMPONENTS      PRINCIPAL DIRECTION       VON MISES
NUMBER           XX          YY          XY          S1            S2                  THETA                  STRESS

   1     (+)   13463.6     1030.7    -4370.6      14846.3       -352.0               -.3064                 15025.4
         (-)  -16639.1    -1245.0     5345.3        429.0     -18313.1               -.3035                 18531.3
   2     (+)   11453.5     2650.7    -9249.4      17295.3      -3191.2               -.5633                 19092.0
         (-)  -13942.4    -2157.4     6832.7        972.6     -17072.4               -.4296                 17579.0
   3     (+)    8165.5     3161.0    -3688.8      10120.6       1205.8               -.4874                  9574.8
         (-)   -8777.3    -1542.5     3162.5       -355.0      -9964.8               -.3592                  9792.1
   4     (+)   26710.2    14406.0     3760.1      27768.2      13348.0                .2743                 24059.0
         (-)  -32091.1   -14876.4    -1965.9     -14654.7     -32312.8                .1123                 28023.9
   5     (+)   16567.8     4282.5    -3695.1      17593.5       3256.8               -.2708                 16212.3
         (-)  -20706.5    -5051.8     1567.1      -4896.4     -20861.8               -.0988                 18895.6
   6     (+)    6446.8      -96.8      280.6       6458.9       -108.8                .0428                  6513.9
         (-)  -10451.0     -102.5     -694.4        -56.2     -10497.4                .0667                 10469.4
   7     (+)   -3705.3    -1464.8     -309.5      -1422.9      -3747.2                .1348                  3276.4
         (-)    -151.7     1160.3      489.8       1323.0       -314.4               -.3207                  1505.1
   8     (+)  -14827.5    -2411.5    -2112.2      -2062.0     -15177.0                .1640                 14258.3
         (-)   10296.8     2088.0     3140.3      11360.3       1024.4                .3265                 10884.3
   9     (+)  -11576.9     1644.4   -12817.6       9455.6     -19388.1                .5473                 25468.4
         (-)    6162.3    -2569.8    15470.5      17871.1     -14278.5                .6479                 27900.2
  10     (+)   14178.0      171.5     -461.2      14193.1        156.3               -.0329                 14115.6
         (-)  -16328.1     -665.3     -266.2       -660.8     -16332.7                .0170                 16012.5
  11     (+)    6428.9    -1907.8       18.7       6428.9      -1907.8                .0022                  7565.5
         (-)   -9604.2     1095.9     -355.4       1107.7      -9616.0                .0332                 10215.0
  12     (+)   -1977.4    -4258.4     -490.5      -1876.4      -4359.4               -.2031                  3787.5
         (-)   -1345.0     3383.5      625.6       3464.9      -1426.4               -.1293                  4356.9
  13     (+)   -9413.4   -10763.4    -2572.1      -7429.2     -12747.6               -.6571                 11090.1
         (-)    6764.7     9480.0     3251.4      11645.8       4598.9               -.5876                 10159.5
  14     (+)  -16707.1    -9043.9    -8661.8      -3404.1     -22346.9                .5772                 20854.2
         (-)   14806.5     8436.7     9689.7      21821.3       1421.9                .6266                 21146.3
  15     (+)   -1405.5    12937.1   -12430.2      20116.3      -8684.8                .5238                 25515.8
         (-)   -3693.2   -13543.8    14724.9       6908.3     -24145.3                .6240                 28240.5
  16     (+)   -5377.8   -20649.7   -10976.5        357.5     -26385.0               -.4815                 26565.5
         (-)    5867.0    21311.4    10970.2      27004.8        173.7               -.4787                 26918.4
  17     (+)  -10401.0   -35663.8    -4069.3      -9761.7     -36303.1               -.1558                 32539.6
         (-)   10481.1    36280.9     4078.6      36910.4       9851.7               -.1531                 33102.9
  18     (+)  -17829.9   -33185.4   -10018.1     -12885.9     -38129.4               -.4584                 33594.1
         (-)   16638.3    32905.6    10464.8      38026.0      11517.9               -.4550                 33773.6
  19     (+)  -16128.6   -12661.7   -24461.3      10127.5     -38917.8                .7500                 44847.5
         (-)   17196.2    15788.8    22832.2      39335.5      -6350.5                .7700                 42865.1
  20     (+)   -6505.7   -42724.1    -6587.4      -5344.8     -43885.0               -.1744                 41471.7
         (-)    6480.2    45591.7     6530.8      46653.4       5418.6               -.1612                 44194.0
  21     (+)    6968.5    13751.3      832.4      13852.0       6867.9               -.1203                 11996.3
         (-)   -9789.7   -13049.1    -2382.0      -8533.2     -14305.6               -.4854                 12465.7
  22     (+)    -194.4    26442.8     9108.5      29259.5      -3011.2               -.2999                 30875.4
         (-)  -12213.0   -32239.1     1528.1     -12097.1     -32355.0                .0757                 28315.8
  23     (+)    4533.4    15788.8     4808.4      17563.3       2758.9               -.3535                 16359.3
         (-)   -2238.5   -13289.4    -6726.8        941.2     -16469.2               -.4416                 16959.4
  24     (+)  -15118.1     8025.5     8265.4      10674.2     -17766.8               -.3101                 24884.7
         (-)   -2083.7   -15613.2     2740.1      -1549.8     -16147.0                .1924                 15430.6
  25     (+)   -7240.6     3387.5    -1932.2       3727.9      -7581.0                .1744                  9981.4
```

TABLE 12. - Output listing, example structure 4--Continued

```
       (-1    11136.4   -2522.3   -3550.1      12004.0    -3389.9          -.2397        14010.0
  26   (+1    -8745.6    3538.0   15271.1      13856.2   -19063.7          -.5942        28628.1
       (-1    -3906.1   -9489.6    -701.7      -3819.3    -9576.4          -.1231         8349.9
  27   (+1    -5950.5    3830.1    3208.6       4788.7    -6909.1          -.2903        10186.0
       (-1     5539.8     897.3   -3342.7       7288.2     -851.1          -.4819         7748.9
  28   (+1   -19783.2    4145.2    2797.2       4467.9   -20105.8          -.1148        22672.4
       (-1    19458.4   -3292.7   -2833.2      19805.9    -3640.2          -.1220        21854.5
  29   (+1     1478.9    7397.2    6594.9      11666.4    -2790.3          -.5745        13283.2
       (-1     1750.8   -3265.2   -6457.7       6170.5    -7684.9          -.6002        12022.9
  30   (+1   -30458.7     451.3   13621.2       5597.1   -35604.5          -.3612        38707.8
       (-1    28600.9    -513.9  -16328.7      35919.2    -7832.1          -.4213        40408.6
  31   (+1   -43501.4   -1647.9  -11746.9       1423.7   -46572.9           .2558        47300.8
       (-1    37218.0     488.7    9882.0      39708.0    -2001.3           .2468        40745.5
  32   (+1   -22492.0    3085.6   -2351.5       3300.0   -22706.4           .0909        24523.5
       (-1    21589.5   -4875.4    2008.8      21741.1    -5027.0           .0753        24642.2
  33   (+1    -7571.0       2.0   -4496.9       2094.3    -9663.2           .4355        10862.9
       (-1     6016.6   -2631.6    4458.0       7903.1    -4518.1           .4003        10889.4
  34   (+1     8749.4   -2737.5   -2250.5       9174.6    -3162.7          -.1867        11099.2
       (-1    -9780.2     933.0    2531.6       1501.1   -10348.3          -.2207        11174.8
  35   (+1     9814.8     552.3    2907.9      10652.0     -285.0           .2803        10797.3
       (-1   -10297.1    1056.2   -2728.1       1677.8   -10918.6           .2240        11846.9
  36   (+1   -10216.8     -28.5  -13959.7       9737.5   -19982.7           .6104        26243.3
       (-1     4590.4   -1007.9   13866.1      15937.1   -12354.5           .6858        24566.7
  37   (+1    21664.4     726.7   -9724.4      25484.0    -3093.0          -.3743        27162.9
       (-1   -27814.4   -1995.2   11398.9       2317.0   -32126.7          -.3617        33345.6
  38   (+1    18211.5    1484.3   14869.9      26908.4    -7212.7           .5292        31147.5
       (-1   -19780.4    -708.0  -12965.8       5850.9   -26339.3           .4683        29700.1
  39   (+1    16232.1   -5704.1  -16892.8      25405.1   -14877.2          -.4975        35280.4
       (-1   -25269.3     954.5     735.3        975.1   -25289.9          -.0280        25791.3
  40   (+1      701.4   -5157.8    3292.6       2179.0    -6635.4           .4218         7952.1
       (-1      333.0    4610.0    -787.7       4750.5      192.5           .1765         4657.2
  41   (+1   -13064.5   -3517.3   13865.1       6373.0   -22954.7          -.6196        26717.5
       (-1    -2975.8    8471.6    3633.1       9527.3    -4031.5          -.2828        12059.5

 . . . PLATE STRESS WARNING-SOME ELEMENTS ARE STRESSED
       ABOVE 36000 PSI. SEE COLUMN OF VON MISES STRESS
       COMPONENTS.
```

TABLE 12. - Output listing, example structure 4--Continued

```
INPUT LOADS,GLOBAL COORDINATE SYSTEM

   X DIRECTION:       0. POUNDS
   Y DIRECTION: -13000. POUNDS
   Z DIRECTION:       0. POUNDS


MAXIMUM LOAD THAT CANOPY CAN SUPPORT IN X DIRECTION IS     -4.  POUNDS
MAXIMUM LOAD THAT CANOPY CAN SUPPORT IN Y DIRECTION IS  12966.  POUNDS
MAXIMUM LOAO THAT CANOPY CAN SUPPORT IN Z DIRECTION IS      1.  POUNDS

 WEIGHT OF BEAM ELEMENTS  =   0. POUNDS
 WEIGHT OF PLATE ELEMENTS = 197. POUNDS
 TOTAL CANOPY WEIGHT      = 197. POUNDS
```

APPENDIX A.--EXTENDED STIFFNESS MATRIX FOR A SPACE-FRAME MEMBER[1]

Protective canopies can possess short, deep members in which the effects of shearing deformations can be significant. To account for these effects, the 12-by-12-member stiffness matrix must be modified. All matrix members that induce lateral shearing forces are extended to account for shearing deformations. It can be shown that this extended stiffness matrix for a space-frame member is--

$$\begin{bmatrix}
\frac{EA_X}{L} & 0 & 0 & 0 & 0 & 0 & \frac{-EA_X}{L} & 0 & 0 & 0 & 0 & 0 \\
0 & \frac{12EI_Z}{L^3(1+2g_Z)} & 0 & 0 & 0 & \frac{6EI_Z}{L^2(1+2g_Z)} & 0 & \frac{-12EI_Z}{L^3(1+2g_Z)} & 0 & 0 & 0 & \frac{6EI_Z}{L^2(1+2g_Z)} \\
0 & 0 & \frac{12EI_Y}{L^3(1+2g_Y)} & 0 & \frac{-6EI_Y}{L^2(1+2g_Y)} & 0 & 0 & 0 & \frac{-12EI_Y}{L^3(1+2g_Y)} & 0 & \frac{-6EI_Y}{L^2(1+2g_Y)} & 0 \\
0 & 0 & 0 & \frac{GI_X}{L} & 0 & 0 & 0 & 0 & 0 & \frac{-GI_X}{L} & 0 & 0 \\
0 & 0 & \frac{-6EI_Y}{L^2(1+2g_Y)} & 0 & \frac{4EI_Y(1+\frac{g_Y}{2})}{L(1+2g_Y)} & 0 & 0 & 0 & \frac{6EI_Y}{L^2(1+2g_Y)} & 0 & \frac{2EI_Y(1-g_Y)}{L(1+2g_Y)} & 0 \\
0 & \frac{6EI_Z}{L^2(1+2g_Z)} & 0 & 0 & 0 & \frac{4EI_Z(1+\frac{g_Z}{2})}{L(1+2g_Z)} & 0 & \frac{-6EI_Z}{L^2(1+2g_Z)} & 0 & 0 & 0 & \frac{2EI_Z(1-g_Z)}{L(1+2g_Z)} \\
\frac{-EA_X}{L} & 0 & 0 & 0 & 0 & 0 & \frac{EA_X}{L} & 0 & 0 & 0 & 0 & 0 \\
0 & \frac{-12EI_Z}{L^3(1+2g_Z)} & 0 & 0 & 0 & \frac{-6EI_Z}{L^2(1+2g_Z)} & 0 & \frac{12EI_Z}{L^3(1+2g_Z)} & 0 & 0 & 0 & \frac{-6EI_Z}{L^2(1+2g_Z)} \\
0 & 0 & \frac{-12EI_Y}{L^3(1+2g_Y)} & 0 & \frac{6EI_Y}{L^2(1+2g_Y)} & 0 & 0 & 0 & \frac{12EI_Y}{L^3(1+2g_Y)} & 0 & \frac{6EI_Y}{L^2(1+2g_Y)} & 0 \\
0 & 0 & 0 & \frac{-GI_X}{L} & 0 & 0 & 0 & 0 & 0 & \frac{GI_X}{L} & 0 & 0 \\
0 & 0 & \frac{-6EI_Y}{L^2(1+2g_Y)} & 0 & \frac{2EI_Y(1-g_Y)}{L(1+2g_Y)} & 0 & 0 & 0 & \frac{6EI_Y}{L^2(1+2g_Y)} & 0 & \frac{4EI_Y(1+\frac{g_Y}{2})}{L(1+2g_Y)} & 0 \\
0 & \frac{6EI_Z}{L^2(1+2g_Z)} & 0 & 0 & 0 & \frac{2EI_Z(1-g_Z)}{L(1+2g_Z)} & 0 & \frac{-6EI_Z}{L^2(1+2g_Z)} & 0 & 0 & 0 & \frac{4EI_Z(1+\frac{g_Z}{2})}{L(1+2g_Z)}
\end{bmatrix}$$

---

[1] Sawyer, S. G. CANOPY--A Computer Program for the Structural Analysis of Space-Frame Protective Canopies. BuMines IC 8546, 1972, 53 pp.

where $g_y = \frac{6fEI_y}{GA_x L^2}$,

$g_z = \frac{6fEI_z}{GA_x L^2}$,

f = form factor for shear; this is a function of the cross section of a structural member,

L = length of member,

A_x = cross-sectional area of member,

E = Young's modulus,

I_y, I_z = moments of inertia about y and z axes, respectively,

G = shear modulus,

and I_x = torsion constant.

If g_y and g_z are set equal to zero, the matrix reduces to that for a three-dimensional beam in which shearing deformations are ignored.

APPENDIX B.--CONDENSATION OF DEGREES OF FREEDOM

The method of static condensation[1] is used to delete the appropriate rotational degrees of freedom when inserting an internal hinge or a plastic hinge in a beam element. The local stiffness matrix and load vector of the element must be modified in the following way to achieve the condensation.

Partition the element stiffness equations, so that $\{d_2\}$ in equation B-1 represents the degree(s) of freedom to be condensed. Thus, if an internal hinge is being applied, $\{d_2\}$ represents the rotational degree of freedom corresponding to the hinge; if a plastic hinge is being applied, $\{d_2\}$ represents the three rotations of the corresponding beam endpoint.

$$\begin{bmatrix} k_{11} & k_{12} \\ k_{21} & k_{22} \end{bmatrix} \begin{Bmatrix} d_1 \\ d_2 \end{Bmatrix} = \begin{Bmatrix} r_1 \\ r_2 \end{Bmatrix} \qquad \text{(B-1)}$$

In equation B-1, solve for $\{d_2\}$ in terms of $\{d_1\}$, obtaining equation B-2:

$$\{d_2\} = [k_{22}]^{-1} (\{r_2\} - [k_{21}]\{d_1\}) \qquad \text{(B-2)}$$

Use equation B-2 to eliminate $\{d_2\}$ from the other equation in B-1 to get

$$([k_{11}] - [k_{12}][k_{22}]^{-1}[k_{21}]) \{d_1\} = \{r_1\} - [k_{12}][k_{22}]^{-1}\{r_2\} \qquad \text{(B-3)}$$

The coefficient of $\{d_1\}$ in equation B-3 is the modified stiffness matrix for a beam element after hinge insertion. The right-hand side of equation B-3 represents the modified load vector. Thus,

$$[k^1] = ([k_{11}] - [k_{12}][k_{22}]^{-1}[k_{21}]) \qquad \text{(B-4)}$$

is the modified beam element stiffness matrix. The size of the matrix $[k^1]$ is still 12 by 12, with a row and column of zeroes corresponding to each deleted degree of freedom. The load vector (right-hand side) in equation B-3 will be the same as the original load vector unless a uniform load is applied along the member; for this case

$$\{r_1'\} = \{r_1\} - [k_{12}][k_{22}]^{-1}\{r_2\} \qquad \text{(B-5)}$$

is the new load vector. $\{r_1'\}$ is expanded to 12 by 1 by adding a zero element corresponding to each deleted degree of freedom.

---

[1] Cook, R. D. Concepts and Applications of Finite Element Analysis. John Wiley & Sons, Inc., New York, 1974, 402 pp.

APPENDIX C.--PLASTIC BENDING MODULUS

Combined stress (bending and axial) on a cross section where a plastic hinge forms is allowed to reach the material yield stress over the entire cross section. Figure C-1 shows a beam member cross section; figure C-2 shows the progression of yielding across the cross section with increased loading. In figure C-2A, the extreme fiber only has reached yield; in figure C-2B, part of the cross section has yielded; and in figure C-2C, the entire cross section has yielded. The plastic moment M_p in figure C-2C is

$$M_p = Z_x \sigma_y , \tag{C-1}$$

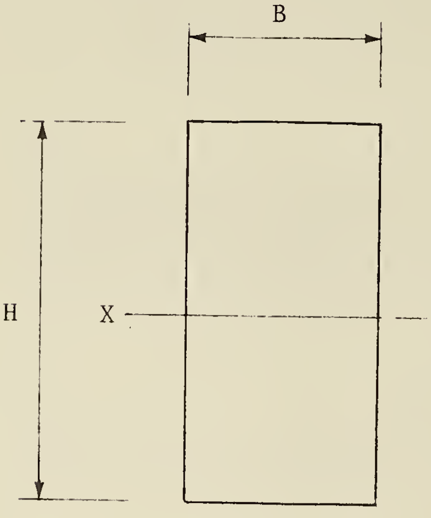
where Z_x = plastic bending modulus (in^3),

and σ_y = material yield stress (psi).

Z_x is the first moment of the areas of the cross section above and below the neutral axis, about the neutral axis.

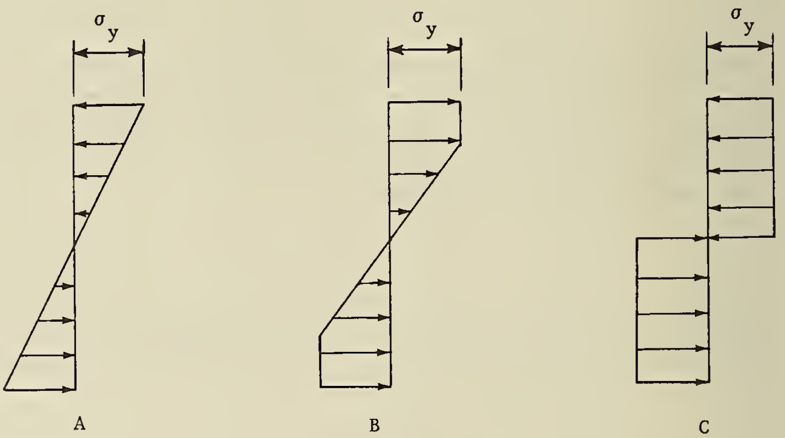
The bending shape factor for a cross section is defined as the ratio of the plastic modulus over the elastic modulus, or

$$SF = Z_x / S_x . \tag{C-2}$$



$$S_X = \frac{1}{6} BH^2$$

FIGURE C-1. - Bending cross section.



σ_y=yield stress, psi

FIGURE C-2. - Stress distributions for elastic, partial plastic, and fully plastic moments.

Typical values of the shape factor are shown in table C-1.

TABLE C-1. - Shape factors for regular cross sections

Cross section	Shape factor
Rectangular solid......................	1.5
Circular solid.........................	1.7
Rectangular tube.......................	1.2 - 1.3
Circular tube..........................	1.3 - 1.4
I-beam.................................	1.1 - 1.15

Shape factors are computed in subroutine PROP for regular cross sections (types 1-5) and input directly for type 6. For an elastic analysis, where only yielding of an extreme fiber is allowed, the shape factor is taken as 1.0 for all cross sections.

APPENDIX D.--LIST OF SYMBOLS

A = Joint load matrix

ACX, ACY, ACZ = Distances from neutral axes to extreme fibers

AE = Equivalent joint load matrix

AML = Fixed end action matrix

AMR = Member end action matrix

AX, A_x = Cross sectional area of beam member

B = Width of beam member

BR = Beam member shape factor for plastic moment

CX, CY, CZ = Direction cosines for beams

D = Height of beam member

E = Young's modulus for beams

EP = Young's modulus for plates

F, f = Beam member shape factor for bending shear

G = Shear modulus for beams

GP = Poisson's ratio for plates

$g_y = \frac{6fEI_y}{GA_x L^2}$

$g_z = \frac{6fEI_z}{GA_x L^2}$

IX = Torsion constant for beam member

IY = Moment of inertia about y axis

IZ = Moment of inertia about z axis

L = Length of beam member

M = Number of beam members in structure

MBAND = Band width of stiffness matrix

NBLOCK = Number of equation blocks

NEQ = Number of structural equations

NEQB = Number of equations per block

NJ = Number of joints in structure

NRJ = Number of restrained joints

NUMPL = Number of plate elements

R = Direction cosine matrix for beam members

RL = Joint restraint matrix

SIGAX = Axial stress in a beam element

SIGBMX = Total maximum bending stress in a beam member

SIGMA1, SIGMA2 = Principal stress in a beam member

SIGMAX = Maximum stress along X_m axis of a beam member

TAUMAX = Maximum torsional stress in a beam member

TF = Flange thickness of member

TW = Web thickness of member

YSTRS = Yield strength

X_m , Y_m , Z_m = Beam-member-oriented coordinate system

X_s , Y_s , Z_s = Structure-oriented coordinate system

APPENDIX E.--PROGRAM LISTING

```
C*************************************************************************
C     STRUCTURAL ANALYSIS OF SPACE FRAME TYPE PROTECTIVE CANOPIES
C     USING THE STIFFNESS METHOD
C*************************************************************************
C     MODIFIED DEC1976 TO INCLUDE SAP THIN SHELL ELEMENT
C***********************************************************************
C     MODIFIED JAN 1977 TO INCLUDE BUCKLING ROUTINE
C***********************************************************************
C     MODIFIED MARCH 1978 TO INCLUDE PLASTIC HINGE
C     IN BEAM ELEMENT
C***********************************************************************
C     NINCR PERTAINS TO THE BUCKLING ROUTINE
C
      PARAMETER NINCR=12
      INTEGER AA,RL,TYPES,TYPE,TYPEM,TOP
      REAL LOADX,LOADY,LOADZ,IXM,IYM,IZM,INCX,INCY,INCZ
      REAL LSQ,L,IX,IY,IZ,MY,MZ
      REAL IXP,IYP,IZP
      COMMON/MPROP/AXP,IXP,IYP,IZP,ACXP,ACYP,ACZP,FP,H,B,TW,TF,TYPES,BRC
      DIMENSION TYPE(20),TYPEM(100)
      DIMENSION AXM(20),IXM(20),IYM(20),IZM(20),ACXM(20),ACYM(20,4),
     1ACZM(20,4),FM(20),YSTRSM(20),BMM(20)
      COMMON/BUCKL/IY(100),IZ(100),X(100),Y(100),Z(100),JJ(100),JK(100),
     1L(100),WY(100),WZ(100),IND1(5),IND2(5),URMY(5,NINCR),URMZ(5,NINCR)
     2,NI1(5),NI2(5),F(100),R(100,9),AX(100),IX(100),WX(100),YSTRS(100)
      DIMENSION RL(600),VMOY(200),ACX(100),ACY(100,4),ACZ(100,4)
      DIMENSION SM(12,12),SMR(12,12),SMD(12,12)
      COMMON/LOADS/A(600),AML(100,12),LML(100),AE(600)
      COMMON/SOLN/DJ(600),AMR(12),JAK(12),TITLE(20)
      DIMENSION SIGMAX(200),SIGAX(200),SIGMA1(200),SIGMA2(200),TAUMAX(20
     10),SIGBMX(200),VMOY2(200),IPL(200),PSIGAX(200),PSIGBM(200),PTAUMX(
     2200),PSIGMX(200),PSIGM1(200),PSIGM2(200),XP(100),YP(100),
     3ZP(100),SMA(12,12),SMA2(12,12),MPL(20),FACTOR(20),RK(40)
      EQUIVALENCE (C(201),SIGAX(1)),(C(401),SIGMAX(1)),(C(601),SIGBMX(1)
     1),(C(801),TAUMAX(1)),(C(1001),SIGMA1(1)),(C(1201),SIGMA2(1)),(C(14
     701)),SMA(1,1)),(C(1701),SMA2(1,1))
      DIMENSION REAC1(20),REAC2(20),REAC3(20),REAC4(20),REAC5(20),REAC6(
     120)
      DIMENSION OJP(600),IR(77),REAC(6),BM(100)
      DIMENSION DEF(20),AMR2(12),ANGL(4),ENERGY(20),PBM(100)
      COMMON/ELPAR/ N1,N3,NEQ
      COMMON/JUNK/ DUM1(24)
      COMMON /EM/  DUM2(1082)
      DIMENSION LM(24),S(24,24),P(24,4),XMT(24)
      COMMON C(3000)
      MTOT=3000
      IFINV=0
C
C     INITIALIZE ARRAYS
C
  944 PRINT 3003
      ISTOP=0
      FACTOR(1)=1.0
      WGTC=0.0
      ENERGT=0.0
      FACTOT=0.0
      REACX=0.0
      REACY=0.0
      REACZ=0.0
      IWH=0
      ICOUNT=0
      ILOAD=0
      LMLT=0
      LNPR=0
  945 ICOUNT=ICOUNT+1
      INT=1
      IF(ICOUNT.NE.1) GO TO 954
 3003 FORMAT(1H1)
      REWIND 2
      REWIND 3
      REWIND 4
      REWIND 10
      REWIND 11
      IF(ILOAD.EQ.0) GO TO 84
C
C     READ PROGRAM OPTIONS, MULTIPLE LOAD CASES
C
      READ 90,IPLAS,DLIMIT,JOINT,IDIREC,IPLOT1,IPLOTD,NVIEW,ISHIFT,IANGL
     1E,DMAG,IPR,NBM
      IF(NVIEW.EQ.0) NVIEW=1
      IF(IPLOT1.EQ.1.OR.IPLOTD.EQ.1) IFINV=1
      IF(IPLAS.NE.1) IPR=1
      IF(DMAG.LT.0.0001) DMAG=1.0
      IPLASP=' NO'
      IF(IPLAS.NE.0) IPLASP='YES'
      IPLOTP=' NO'
      IF(IPLOT1.NE.0) IPLOTP='YES'
      IPLOTQ=' NO'
      IF(IPLOTD.NE.0) IPLOTQ='YES'
      NOD6=JOINT*6-5
      IF(IDIREC.EQ.2) NOD6=NOD6+1
      IF(IDIREC.EQ.3) NOD6=NOD6+2
      IF(IANGLE.EQ.0) THETA=120.0
      IF(IANGLE.EQ.0) PHI=30.0
      PRINT 3003
      PRINT 310,IPLASP,IPLOTP,IPLOTQ,NBM
      IF(IPLAS.EQ.1) GO TO 954
      DO 82 JS=1,M
   82 BM(JS)=1.0
      GO TO 954
   84 CONTINUE
        MBAND = 0
      NUMEL  = 0
C     SET MULTI-LOAD CASE PARAMETER (SAP) EQUAL TO ONE
C     LOAD CASES ARE TO BE SOLVED ONE-AT-A-TIME IN CANOPY
      LL = 1
      DO 131 I=1,100
      WX(I)=0.
      WY(I)=0.
      WZ(I)=0.
      LML(I)=0
      IF(I.LE.77) IR(I)=0
      DO 131 J=1,12
      IF(J.LE.9) R(I,J)=0.
      IF(I.LE.12) SM(I,J)=0.
  131 AML(I,J)=0.
      DO 132 I=1,600
      A(I)=0.
      AE(I)=0.
      RL(I)=0
      DJP(I)=0.0
  132 CONTINUE
      DO 138 I=1,200
      VMOY(I)=0.0
      VMOY2(I)=0.0
      IPLY(I)=0
      PSIGAX(I)=0.0
      PSIGBM(I)=0.0
      PTAUMX(I)=0.0
      PSIGMX(I)=0.0
      PSIGM1(I)=0.0
138   PSIGM2(I)=0.0
      DO 147 K=1,20
      REAC1(K)=0.0
      REAC2(K)=0.0
      REAC3(K)=0.0
      REAC4(K)=0.0
      REAC5(K)=0.0
147   REAC6(K)=0.0
C
C     STRUCTURE DATA
C
      READ 647,(TITLE(JQ),JQ=1,14)
647   FORMAT(13A6,A2)
      PRINT 648,(TITLE(JR),JR=1,14)
648   FORMAT(//,30X,' - -   P L A S T I C   C A N O P Y   R E S U L T S
     2- - ',//,13A6,A2)
C
C   READ PROGRAM OPTIONS
C
C   DLIMIT: MAX DEFLECTION   JOINT:NODE WITH LIMITED DEFLECTION
C   IDIREC: GLOBAL DIRECTION OF LIMITATION, 1=X,2=Y,3=Z
      READ 90,IPLAS,DLIMIT,JOINT,IDIREC,IPLOTI,IPLOTD,NVIEW,ISHIFT,IANGL
     1E,DMAG,IPR,NBM
90    FORMAT(I5,F10.2,7I5,F10.2,2I5)
      IF(NVIEW.EQ.0) NVIEW=1
      IF(IPLOTI.EQ.1.OR.IPLOTD.EQ.1) IFINV=1
      IF(IPLAS.NE.1) IPR=1
      IF(DMAG.LT.0.0001) DMAG=1.0
      IF(IPLAS.NE.1) IPR=1
      IF(IANGLE.EQ.0) THETA=120.0
      IF(IANGLE.EQ.0) PHI=30.0
      NOD6=JOINT*6-5
      IF(IDIREC.EQ.2) NOD6=NOD6+1
      IF(IDIREC.EQ.3) NOO6=NOD6+2
      IPLASP=' NO'
      IF(IPLAS.NE.0) IPLASP='YES'
      IPLOTP=' NO'
      IF(IPLOTI.NE.0) IPLOTP='YES'
      IPLOTQ=' NO'
      IF(IPLOTD.NE.0) IPLOTQ='YES'
      READ 100,NST,NJ,NNC,NMTP,M,NMC,NUMPL,NRJ,NLS,E,G,EP,GP
      M2=M*2
100   FORMAT(9I5,3F10.0,F5.3)
      IF(NST.LE.0) NST=1
      IF(NLS.LE.0)GO TO 1500
C *** OEFAULT VALUES FOR ZERO OR BLANK ENTRIES
      IF(G.LE.0) G=0.5*E
      IF(EP.LE.0) EP=E
      IF(GP.LE.0I GP=0.5*E/G -1.0
      IF(GP.LT.0.0) GO TO 1500
      IF(GP.GT.0.49) GO TO 1500
      N=NJ*6
      PRINT 300,NJ,NNC,NMTP,M,NMC,NUMPL,NRJ,NLS,NST,E,G,EP,GP
300   FORMAT(///,
     1'               * *  S T R U C T U R E   D A T A',//,15X,'NUMBER OF JOI
     INTS=',I4,//,15X,'NUMBER OF JT. DESIGNATION CARDS=',I4,//,15X,'NUMB
     2ER OF BEAM GEOMETRIES=',I4,//,15X,'NUMBER OF BEAM ELEMENTS=',I4,//
     3,15X,'NUMBER OF BEAM ELEMENT DESIGNATION CAROS=',I4,//,15X,'NUMBER
     4 OF PLATE ELEMENTS=',I4,//,15X,'NUMBER OF RESTRAINED JOINTS=',I4,/
     5/,15X,'NUMBER OF LOAOING CONDITIONS=',I4,//,15X,'NUMBER OF STRUCTU
     6RE GEOMETRIES=',I4,//,15X,'YOUNG S MODULUS FOR BEAMS=',F10.0,//,15
     7X,'SHEAR MODULUS FOR BEAMS=',F10.0,//,15X,'YOUNG S MOOULUS FOR PLA
     8TES=',F10.0,//,15X,'POISSON RATIO FOR PLATES=',F4.2)
      PRINT 310,IPLASP,IPLOTP,IPLOTQ,NBM
310   FORMAT(///,
     1'               * *  P R O G R A M   O P T I O N S',//,15X,'PLASTIC ANA
     1LYSIS:',2x,A3,//,15X,'PLOT UNDEFORMEO GEOMETRY:',2X,A3,//,15X,'PLO
     2T OEFORMED GEOMETRY:',2X,A3,//,15X,'NO. OF BUCKLING ELEMENTS:',2X,
     3I2I
      IF(N.GT.600I GO TO 1492
      IF(M.GT.0) PRINT 3378
      IF(M.GT.0) PRINT 3379
3378  FORMAT(1H1,///,15X,' - - O U T P U T   A B B R E V I A T I O N S '
     1,///,5X,'ABBREVIATIONS USED IN BEAM MEMBER PROPERTIES TABLE',//,10
     2X,'JJ =NODAL NUMBER OF BEAM ENDPOINT',/,10X,'JK =NOOAL NUMBER OF B
     3EAM ENDPOINT',/,10X,'AX =CROSS SECTIONAL AREA',/,10X,'Ix =TORSIONA
     4L MOMENT OF INERTIA',/,10X,'IY =BENOING MOMENT OF INERTIA,LOCAL Y-
     5AXIS',/,10X,'IZ =BENDING MOMENT OF INERTIA,LOCAL Z-AXIS',/,10X,'AA
     6 =FLAG DENOTING BEAM ELEMENT ROTATION',/,10X,'ACX=DISTANCE TO EXTR
     7EME FIBER,TORSION',/,10X,'ACY=OISTANCE TO EXTREME FIBER,M(Z)',/,10
     8X,'ACZ=DISTANCE TO EXTREME FIBER,M(Y)',/,10X,'F  =GEOMETRIC FORM F
     IACTOR,SHEAR DEFORMATIONS',/,10X,'BM =RATIO OF PLASTIC TO ELASTIC B
     2ENDING MODULUS',/,10X,'YIELD=MATERIAL YIELD STRESS,PSI',/,10X,'L
     3=MEMBER LENGTH,INCHES',/,10X,'CX =DIRECTION COSINE',/,10X,'CY =DIR
     4ECTION COSINE',/,10X,'CZ =DIRECTION COSINE')
3379  FORMAT(//,5X,'ABBREVIATIONS USED IN BEAM MEMBER STRESS TABLE',
     1//,10X,'SIGBMX=COMBINED BENDING STRESS ABOUT PRINCIPAL AXES',/,10X
     2,'SIGAX =AXIAL STRESS',/,10X,'TAUMAX=TORSIONAL SHEAR STRESS',/,10X
     3,'SIGMAX=BENDING PLUS AXIAL STRESS',/,10X,'SIGMA1=PRINCIPAL STRESS
     3',/,10X,'SIGMA2=PRINCIPAL STRESS',/,10X,'VMISES=VON MISES EFFECTIV
     4E STRESS',/,10X,'VMISES/ALLOW=RATIO VON MISES TO MATERIAL YIELD ST
     5RESS',/,10X,'HINGE =NON ZERO ENTRY DENOTES PLASTIC HINGE')
C
C      INPUT COORDINATES OF JOINTS
C
      DO 102 JO=1,NNC
      READ 103, JP,J1,(X(JP),Y(JP),Z(JP),X(J1),Y(J1),Z(J1)),JINCR
  103 FORMAT(2I5,6F10.3,I5)
      IF(JP.EQ.J1) GO TO 102
      INCX=(X(J1)-X(JP))/(J1-JP)
      INCY=(Y(J1)-Y(JP))/(J1-JP)
      INCZ=(Z(J1)-Z(JP))/(J1-JP)
      IF(JINCR.LT.1) JINCR=1
      DO 142 J=JP,J1,JINCR
      X(J)=X(JP)+INCX*(J-JP)
      Y(J)=Y(JP)+INCY*(J-JP)
      Z(J)=Z(JP)+INCZ*(J-JP)
  142 CONTINUE
  102 CONTINUE
      MPRINT=0
      DO 1745 J=1,NJ
      IF(MPRINT.NE.0) GO TO 1
      PRINT 3003
      PRINT 301
  301 FORMAT(22H COORDINATES OF JOINTS,/,33H JOINT        X           Y
     1     Z)
      MPRINT=50
    1 MPRINT=MPRINT-1
 1745 PRINT 293, J,X(J),Y(J),Z(J)
  293 FORMAT(I5,3F10.2)
C
C      INPUT AND CALCULATE MEMBER SECTION PROPERTIES AND YIELD STRENGTH
C
      IF(NMTP.LE.0)GO TO 365
      DO 364 III=1,NMTP
      READ 477, I,TYPE(I),YSTRSM(I),H,B,TW,TF
  477 FORMAT(2I5,F10.0,4F10.4)
      IF(TYPE(I).NE.6) GO TO 701
      READ 478,AXP,IXP,IYP,IZP,ACXP,FP,BRC
      IF(BRC.LT.0.001) BRC=1.0
478   FORMAT(7F10.3)
      READ 487, ACYM(I,1),ACZM(I,1),ACYM(I,2),ACZM(I,2),ACYM(I,3),
     1                ACZM(I,3),ACYM(I,4),ACZM(I,4)
  487 FORMAT(8F10.3)
      GO TO 363
  701 TYPES=TYPE(I)
      CALL PROP
      ACYM(I,1)=ACYP
      ACZM(I,I)=ACZP
  363 AXM(I)=AXP
      IXM(I)=IXP
      IYM(I)=IYP
      IZM(I)=IZP
      ACXM(I)=ACXP
      BMM(I)=BRC
  364 FM(I)=FP
365   CONTINUE
C
C     INPUT MEMBER DESIGNATIONS AND ORIENTATIONS
C
      IF(NMC.LE.0) GO TO 931
      MPRINT=0
      DO 104 III=1,NMC
C
C     INPUT FOR RELEASES ARE READ FROM MEMBER DESIGNATION CARDS
C     RELEASES ARE REFERRED TO THE MEMBER COORDINATE SYSTEM
C     THE ARRAY IR KEEPS TRACK OF ALL MEMBERS WITH RELEASES AND WHICH
C     ROTATIONS ARE AFFECTED IN EACH
C
      READ 105,IP,JI,JJ(IP),JK(IP),AA,MTP,MINCR,IX1,IY1,IZ1,IX2,IY2,IZ2
105   FORMAT(13I5)
      INT=IX1+IY1+IZ1+IX2+IY2+IZ2
      IF(INT.EQ.0)GO TO 2104
      IR(INT)=IP
      IR(INT+1)=IX1
      IR(INT+2)=IY1
      IR(INT+3)=IZ1
      IR(INT+4)=IX2
      IR(INT+5)=IY2
      IR(INT+6)=IZ2
      IWH=IWH+1
      INT=INT+7
2104  CONTINUE
      IF(AA.EQ.1) READ 108,XP(IP),YP(IP),ZP(IP)
  108 FORMAT(3F10.5)
C
C     BEAM ELEMENT GENERATION LOOP
C
      DO 104 I=IP,JI
      JJ(I)=JJ(IP)+(I-IP)*MINCR
      JK(I)=JK(IP)+(I-IP)*MINCR
      IF(JJ(I).LT.JK(I)) GO TO 240
      J=JJ(I)
      JJ(I)=JK(I)
      JK(I)=J
      XP(I)=XP(IP)
      YP(I)=YP(IP)
      ZP(I)=ZP(IP)
  240 CONTINUE
      JKI=JK(I)
      JJI=JJ(I)
      XCL=X(JKI)-X(JJI)
      YCL=Y(JKI)-Y(JJI)
      ZCL=Z(JKI)-Z(JJI)
      L(I)=SQRT(XCL**2+YCL**2+ZCL**2)
      CX=XCL/L(I)
      CY=YCL/L(I)
      CZ=ZCL/L(I)
      AX(I)=AXM(MTP)
      IX(I)=IXM(MTP)
      IY(I)=IYM(MTP)
      IZ(I)=IZM(MTP)
      BM(I)=BMM(MTP)
      PBM(I)=BMM(MTP)
      IF(IPLAS.NE.1) BM(I)=1.0
      ACX(I)=ACXM(MTP)
      TYPEM(I)=TYPE(MTP)
      TOP=TYPEM(I)
      ICOR=1
      IF(TOP.EQ.6) ICOR=4
      DO 847 JOE=1,ICOR
      ACY(I,JOE)=ACYM(MTP,JOE)
  847 ACZ(I,JOE)=ACZM(MTP,JOE)
      F(I)=FM(MTP)
      YSTRS(I)=YSTRSM(MTP)
      IF(MPRINT.GT.0) GO TO 2
      PRINT 3003
      PRINT 302
302   FORMAT(48H MEMBER DESIGNATIONS,PROPERTIES,AND ORIENTATIONS,/,109H
     1MEMBER  JJ   JK    AX     IX    IY     IZ   AA  ACX    ACY   ACZ    F
     2    BM   YIELD    L       CX     CY      CZ  )
      MPRINT=50
    2 MPRINT=MPRINT-1
      PRINT 106, I,JJ(I),JK(I),AX(I),IX(I),IY(I),IZ(I),AA,ACX(I),
     1  ACY(I,1),ACZ(I,1),F(I),BM(I),YSTRS(I),L(I),CX,CY,CZ
106   FORMAT(3I5,4F6.2,I4,5F6.2,F8.0,4F7.2)
      IF(ICOR.EQ.1) GO TO 925
      DO 924 JIG=2,4
      MPRINT=MPRINT-1
      IF(MPRINT.LE.3) MPRINT=0
  924 PRINT 926, ACY(I,JIG),ACZ(I,JIG)
  926 FORMAT(49X,2F6.2)
  925 CONTINUE
C
C     CALCULATE ROTATIONAL MATRIX
C
      Q=SQRT(CX**2+CZ**2)
      IF(AA.NE.1) GO TO 107
      JJI=JJ(I)
      XPS=XP(I)-X(JJI)
      YPS=YP(I)-Y(JJI)
      ZPS=ZP(I)-Z(JJI)
  107 IF(Q.GE.0.001) GO TO 109
      R(I,4)=-CY
      R(I,2)=CY
      R(I,9)=1.0
      IF(AA.NE.1) GO TO 104
      SQ=SQRT(XPS**2+ZPS**2)
      SINA=ZPS/SQ
      COSA=-XPS*CY/SQ
      R(I,4)=-CY*COSA
      R(I,6)=SINA
      R(I,7)=CY*SINA
      R(I,9)=COSA
      GO TO 104
  109 R(I,1)=CX
      R(I,2)=CY
      R(I,3)=CZ
      R(I,4)=-CX*CY/Q
      R(I,5)=Q
      R(I,6)=-CY*CZ/Q
      R(I,7)=-CZ/Q
      R(I,9)=CX/Q
      IF(AA.NE.1) GO TO 104
      YPG=R(I,4)*XPS+R(I,5)*YPS+R(I,6)*ZPS
      ZPG=R(I,7)*XPS+R(I,8)*YPS+R(I,9)*ZPS
      SQ=SQRT(YPG**2+ZPG**2)
      COSA=YPG/SQ
      SINA=ZPG/SQ
      R(I,4)=(-CX*CY*COSA-CZ*SINA)/Q
      R(I,5)=Q*COSA
      R(I,6)=(-CY*CZ*COSA+CX*SINA)/Q
      R(I,7)=(CX*CY*SINA-CZ*COSA)/Q
      R(I,8)=-Q*SINA
      R(I,9)=(CY*CZ*SINA+CX*COSA)/Q
  104 CONTINUE
C
C     GENERATE STIFFNESS FOR EACH BEAM ELEMENT
C
954   CONTINUE
      I=0
      INT=1
      WGTC=0.
  932 I=I+1
      IF(I.GT.M) GO TO 931
      WGTC=WGTC+L(I)*AX(I)*.2836
  357 CONTINUE
      J1=6*JJ(I)-5
      J2=6*JJ(I)-4
      J3=6*JJ(I)-3
      J4=6*JJ(I)-2
      J5=6*JJ(I)-1
      J6=6*JJ(I)
      K1=6*JK(I)-5
      K2=6*JK(I)-4
      K3=6*JK(I)-3
      K4=6*JK(I)-2
      K5=6*JK(I)-1
      K6=6*JK(I)
      GY=(6.*F(I)*E*IY(I))/(G*AX(I)*L(I)**2)
      GZ=(6.*F(I)*E*IZ(I))/(G*AX(I)*L(I)**2)
      CFY1=1./(1.+2.*GY)
      CFZ1=1./(1.+2.*GZ)
      CFY2=(1.+GY/2.)*CFY1
      CFZ2=(1.+GZ/2.)*CFZ1
      CFY3=(1.-GY)*CFY1
      CFZ3=(1.-GZ)*CFZ1
      SCM1=(E*AX(I))/L(I)
      SCM2=(12.*E*IZ(I)*CFZ1)/L(I)**3
      SCM3=(6.*E*IZ(I)*CFZ1)/L(I)**2
      SCM4=(12.*E*IY(I)*CFY1)/L(I)**3
      SCM5=(6.*E*IY(I)*CFY1)/L(I)**2
      SCM6=(G*IX(I))/L(I)
      SCM7=(4.*E*IY(I)*CFY2)/L(I)
      SCM8=(2.*E*IY(I)*CFY3)/L(I)
      SCM9=(4.*E*IZ(I)*CFZ2)/L(I)
      SCM10=(2.*E*IZ(I)*CFZ3)/L(I)
      SM(1,1)=SCM1
      SM(7,7)=SCM1
      SM(1,7)=-SCM1
      SM(2,2)=SCM2
      SM(8,8)=SCM2
      SM(2,8)=-SCM2
      SM(2,6)=SCM3
      SM(2,12)=SCM3
      SM(6,8)=-SCM3
      SM(8,12)=-SCM3
      SM(3,3)=SCM4
      SM(9,9)=SCM4
      SM(3,9)=-SCM4
      SM(3,5)=-SCM5
      SM(3,11)=-SCM5
      SM(4,4)=SCM6
      SM(4,10)=-SCM6
      SM(10,10)=SCM6
      SM(5,5)=SCM7
      SM(11,11)=SCM7
      SM(5,11)=SCM8
      SM(6,6)=SCM9
      SM(12,12)=SCM9
      SM(9,11)=SCM5
      SM(5,9)=SCM5
      SM(6,12)=SCM10
      DO 204 II=2,12
      III=II-1
      DO 204 JJJ=1,III
 204  SM(II,JJJ)=SM(JJJ,II)
C
C     RELEASE ROTATIONAL DOF,INTERNAL HINGE
C
      IF(IR(INT).NE.1) GO TO 3900
      DO 3895 ICT=1,6
      IF(IR(INT+ICT).EQ.0) GO TO 3895
      INR=INR+1
      IF(ICT.EQ.1) GO TO 3901
      IF(ICT.EQ.2) GO TO 3902
      IF(ICT.EQ.3) GO TO 3903
      IF(ICT.EQ.4) GO TO 3904
      IF(ICT.EQ.5) GO TO 3905
      IF(ICT.EQ.6) GO TO 3906
 3901 IT=10
      JT=4
      SM(IT,IT)=0.0
      SM(IT,JT)=0.0
      SM(JT,IT)=0.0
      GO TO 3895
 3902 JT=5
      GO TO 3907
 3903 JT=6
      GO TO 3907
 3904 IT=4
      JT=10
      SM(IT,IT)=0.0
      SM(IT,JT)=0.0
      SM(JT,IT)=0.0
      GO TO 3895
 3905 JT=11
      GO TO 3907
 3906 JT=12
 3907 CONTINUE
      DO 1770 J=1,12
      DO 1770 K=1,12
 1770 SMA(J,K)=SM(J,K)-SM(J,JT)*SM(JT,K)/SM(JT,JT)
      DO 1780 J=1,12
      DO 1780 K=1,12
 1780 SM(J,K)=SMA(J,K)
 3895 CONTINUE
      INT=INT+7
 3900 CONTINUE
C
C     RELEASE ROTATIONAL DOF,PLASTIC HINGE
C
      IHI1= I*2-1
      IHI2= I*2
      IF(ICOUNT.EQ.1)GO TO 3205
      IF(IPL(IHI1).EQ.0.AND.IPL(IHI2).EQ.0) GO TO 3205
      IF(IPL(IHI1).EQ.0) GO TO 3206
      DO 770 I=1,12
      DO 770 J=1,12
 770  SMA(I,J)=SM(I,J)-SM(I,4)*SM(4,J)/SM(4,4)
      DO 771 I=1,12
      DO 771 J=1,12
 771  SMA2(I,J)=SMA(I,J)-SMA(I,5)*SMA(5,J)/SMA(5,5)
      DO 772 I=1,12
      DO 772 J=1,12
 772  SM(I,J)=SMA2(I,J)-SMA2(I,6)*SMA2(6,J)/SMA2(6,6)
 3206 IF(IPL(IHI2).EQ.0) GO TO 3205
      DO 780 I=1,12
      DO 780 J=1,12
780   SMA(I,J)=SM(I,J)-SM(I,10)*SM(10,J)/SM(10,10)
      DO 781 I=1,12
      DO 781 J=1,12
781   SMA2(I,J)=SMA(I,J)-SMA(I,11)*SMA(11,J)/SMA(11,11)
      DO 782 I=1,12
      DO 782 J=1,12
782   SM(I,J)=SMA2(I,J)-SMA2(I,12)*SMA2(12,J)/SMA2(12,12)
3205  CONTINUE
      WRITE (18) ((SM(I,J),I=1,12),J=1,12)
      DO 205 K=1,4
      DO 205 J=1,12
      SMR(J,3*K-2)=SM(J,3*K-2)*R(I,1)+SM(J,3*K-1)*R(I,4)+SM(J,3*K)
     1*R(I,7)
      SMR(J,3*K-1)=SM(J,3*K-2)*R(I,2)+SM(J,3*K-1)*R(I,5)+SM(J,3*K)
     1*R(I,8)
      SMR(J,3*K)=SM(J,3*K-2)*R(I,3)+SM(J,3*K-1)*R(I,6)+SM(J,3*K)*R(I,9)
  205 CONTINUE
      DO 206 J=1,4
      DO 206 K=1,12
      SMD(3*J-2,K)=R(I,1)*SMR(3*J-2,K)+R(I,4)*SMR(3*J-1,K)+R(I,7)*SMR(
     1 3*J,K)
      SMD(3*J-1,K)=R(I,2)*SMR(3*J-2,K)+R(I,5)*SMR(3*J-1,K)+R(I,8)*SMR(
     1 3*J,K)
      SMD(3*J,K)=R(I,3)*SMR(3*J-2,K)+R(I,6)*SMR(3*J-1,K)+R(I,9)*SMR(
     1 3*J,K)
  206 CONTINUE
      JAK(1)=J1
      JAK(2)=J2
      JAK(3)=J3
      JAK(4)=J4
      JAK(5)=J5
      JAK(6)=J6
      JAK(7)=K1
      JAK(8)=K2
      JAK(9)=K3
      JAK(10)=K4
      JAK(11)=K5
      JAK(12)=K6
      CALL BEAM (JAK,SMD,MBAND)
      GO TO 932
  931 CONTINUE
C
C    WRITE JOINT COORDINATES INTO XP,YP,ZP ARRAYS
C    FOR DEFORMED PLOTS
C
      IF(ICOUNT.GT.1) GO TO 3678
      DO 3578 IUP=1,NJ
      XP(IUP)=X(IUP)
      YP(IUP)=Y(IUP)
3578  ZP(IUP)=Z(IUP)
3678  CONTINUE
C
C     CALL TPLATE TO FORM PLATE ELEMENTS
```

```
C
      IF(NUMPL.GT.0.AND.ICOUNT.EQ.1.AND.ILOAD.NE.1)
     *CALL TPLATE(NUMPL,X,Y,Z,NJ,MBAND,EP,GP,AREAT)
      VTPL=AREAT
      IF(NUMPL.GT.0.AND.ICOUNT.EQ.1.AND.ILOAD.NE.0) GO TO 4519
      IF(NUMPL.EQ.0.OR.ICOUNT.EQ.1) GO TO 4521
4519  DO 4520 JPT=1,NUMPL
      READ(11) LRD,ND,(LM(I),I=1,ND),((S(I,J),I=1,ND),J=1,ND),((P(I,J),I
     1=1,ND),J=1,4),(XMT(I),I=1,ND)
      WRITE(8) LRD,ND,(LM(I),I=1,ND),((S(I,J),I=1,ND),J=1,ND),((P(I,J),I
     1=1,ND),J=1,4),(XMT(I),I=1,ND)
4520  CONTINUE
4521  REWIND 11
C
C
C     INPUT JOINT RESTRAINTS
C
      IF(ICOUNT.GT.1.OR.ILOAD.EQ.1) GO TO 112
      MPRINT=0
      DO 110 J=1,NRJ
      READ 181, K,RL(6*K-5),RL(6*K-4),RL(6*K-3),RL(6*K-2),RL(6*K-1),
     1RL(6*K)
  181 FORMAT(7I5)
      IF(MPRINT.NE.0) GO TO 3
      PRINT 3003
      PRINT 303
  303 FORMAT(17H JOINT RESTRAINTS,/,71H       JOINT   X TRANS.  Y TRANS.
     1Z TRANS.    X ROTA.    Y ROTA.    Z ROTA.)
      MPRINT=56
    3 MPRINT=MPRINT-1
      PRINT 111,K,RL(6*K-5),RL(6*K-4),RL(6*K-3),RL(6*K-2),RL(6*K-1),
     1RL(6*K)
  111 FORMAT(7I10)
  110 CONTINUE
112   CONTINUE
C
C     BOUNDARY ELEMENT ROUTINE  -  LARGE SPRING ON DIAGONAL
C
      NBC = 0
      NJ6=6*NJ
      DO 116  K=1,NJ6
      IF(RL(K).NE.1) GO TO 116
      NBC = NBC+1
      CALL BOUND (K,MBAND)
  116 CONTINUE
C
C
      NUMEL = M + NUMPL + NBC
      NEQ = 6*NJ
      NEQB=(MTOT-4*LL)/(MBAND+LL+1)/2
      NBLOCK=(NEQ-1)/NEQB +1
      IF (NEQB.GT.NEQ) NEQB=NEQ
      IF(ICOUNT.EQ.1.AND.ILOAD.EQ.0)
     *PRINT 201,NEQ,MBAND,NEQB,NBLOCK
```

```
201   FORMAT(1H1,30H E Q U A T I O N   P A R A M E T E R S,/
     1        /30H   TOTAL NUMBER OF EQUATIONS =,I5,                    .
     2        /30H   BANDWIDTH                 =,I5,                    .
     3        /30H   NUMBER OF EQNS IN A BLOCK =,I5,                    .
     4        /30H   NUMBER OF BLOCKS          =,I5)                    .
      IF(ICOUNT.GT.1)
     *REWIND 3
      IF(ICOUNT.GT.1) GO TO 216
C                                                                       .
C                                                                       .
C     START LOAD CASE LOOP                                              .
      LN=0
  943 LN=LN+1
      LOADX=0.
      LOADY=0.
      LOADZ=0.
      IF(LN.LE.1) GO TO 500
      DO 510 II=1,100
      WX(II)=0.
      WY(II)=0.
      WZ(II)=0.
      LML(II)=0
      DO 510 JJJ=1,12
  510 AML(II,JJJ)=0.
      DO 520 II=1,600
      A(II)=0.
  520 AE(II)=0.
  500 CONTINUE
C
C     INPUT LOAD DATA
      READ 2134,NLJC,NLMC
2134  FORMAT(2I5)
      LNPR=LNPR+1
      PRINT 3003
      PRINT 313,LNPR
313   FORMAT(///,'   LOADING NUMBER',I3,/)
      PRINT 314,NLJC,NLMC
314   FORMAT('    NO. OF LOADED JOINT CAROS  =',I3,/,
     1       '    NO. OF LOAOEO MEMBER CARDS =',I3,//)
      IF(NLJC.EQ.0) GO TO 210
      MPRINT=0
      OO 211 J=1,NLJC
      READ 292, KI,KJ,INCRP,AFX,AFY,AFZ,AMX,AMY,AMZ
  292 FORMAT(3I5,6F10.0)
      IF(INCRP.LT.1) INCRP=1
      DO 211 K=KI,KJ,INCRP
      A(6*K-5)=AFX
      A(6*K-4)=AFY
      A(6*K-3)=AFZ
      A(6*K-2)=AMX
      A(6*K-1)=AMY
      A(6*K)=AMZ
      LOADX=LOADX+A(6*K-5)
      LOADY=LOADY+A(6*K-4)
      LOADZ=LOADZ+A(6*K-3)
      IF(MPRINT.NE.0) GO TO 4
      PRINT 305
  305 FORMAT(26H ACTIONS APPLIED AT JOINTS,/,66H JOINT    X FORCE   Y FOR
     1CE   Z FORCE  X MOMENT  Y MOMENT  Z MOMENT)
      MPRINT=50
    4 MPRINT=MPRINT-1
      PRINT 212,K,A(6*K-5),A(6*K-4),A(6*K-3),A(6*K-2),A(6*K-1),A(6*K)
  212 FORMAT(I5,6F10.0)
  211 CONTINUE
  210 IF(NLMC.EQ.0) GO TO 217
      MPRINT=0
      DO 215 J=1,NLMC

      READ 669, MI,MJ,INCRW,WXB,WYB,WZB
  669 FORMAT(3I5,3F10.3)
      IF(INCRW.LT.1) INCRW=1
      DO 215 I=MI,MJ,INCRW
      IF(MPRINT.NE.0) GO TO 5
      PRINT 306
  306 FORMAT(29H DISTRIBUTED LOADS ON MEMBERS,/,34H MEMBER      WX
     1 WY         WZ )
      MPRINT=50
    5 MPRINT=MPRINT-1
      PRINT 2624, I,WXB,WYB,WZB
 2624 FORMAT(I5,3F10.2)
      LML(I)=1
      LMLT=LMLT+LML(I)
      WX(I)=WXB*R(I,1)+WYB*R(I,2)+WZB*R(I,3)
      WY(I)=WXB*R(I,4)+WYB*R(I,5)+WZB*R(I,6)
      WZ(I)=WXB*R(I,7)+WYB*R(I,8)+WZB*R(I,9)
215   CONTINUE
216   CONTINUE
      NJ6=NJ*6
      DO 3646 K=1,NJ6
3646  AE(K)=0.0
C
C     CALCULATE ACTIONS AT ENDS OF RESTRAINED MEMBERS DUE TO LOADS
C
      IF(LMLT.EQ.0) GO TO 217
      DO 218 I=1,M
      IF(LML(I).NE.1) GO TO 218
      LSQ=L(I)**2
      AML(I,1)=-WX(I)*L(I)/2.
      AML(I,2)=-WY(I)*L(I)/2.
      AML(I,3)=-WZ(I)*L(I)/2.
      AML(I,4)=0.
      AML(I,5)=WZ(I)*LSQ/12.
      AML(I,6)=-WY(I)*LSQ/12.
      AML(I,7)=-WX(I)*L(I)/2.
      AML(I,8)=-WY(I)*L(I)/2.
      AML(I,9)=-WZ(I)*L(I)/2.
      AML(I,10)=0.
      AML(I,11)=-WZ(I)*LSQ/12.
      AML(I,12)=WY(I)*LSQ/12.
      J1=6*JJ(I)-5
      J2=6*JJ(I)-4
      J3=6*JJ(I)-3
      J4=6*JJ(I)-2
      J5=6*JJ(I)-1
      J6=6*JJ(I)
      K1=6*JK(I)-5
      K2=6*JK(II-4
      K3=6*JK(I)-3
      K4=6*JK(I)-2
      K5=6*JK(II-1
      K6=6*JK(I)
      IC1=2*I-1
      IC2=IC1+1
      IY1=0
      IY2=0
      IZ1=0
      IZ2=0
      IF(IWH.EQ.0) GO TO 1235
      IHI=0
      DO 1225 J=1,IWH
      JT=(J-1)*7+1
 1225 IF(IR(JT).EQ.1) IHI=JT
      IF(IHI.EQ.0) GO TO 1235
      IF(IR(JI+2).NE.0) IY1=1
      IF(IR(JT+3).NE.0) IZ1=1
      IF(IR(JT+5).NE.0) IY2=1
      IF(IR(JT+6).NE.0) IZ2=1
 1235 IF(IPL(IC1).EQ.0.AND.IPL(IC2).EQ.0) GO TO 1265
      IF(IPL(IC1).EQ.0I GO TO 1245
      IY1=1
      IZ1=1
 1245 IF(IPL(IC2).EQ.0) GO TO 1265
      IY2=1
      IZ2=1
 1265 CONTINUE
      IF(IY1.EQ.1.AND.IY2.EQ.1) GO TO 1310
      IF(IY1.EQ.1.AND.IY2.EQ.0) GO TO 1320
      IF(IY1.EQ.0.AND.IY2.EQ.1) GO TO 1330
      GO TO 1350
 1310 AML(I,5)=0.0
      AML(I,11)=0.0
      GO TO 1350
 1320 AML(I,3)=-0.375*WZ(I)*L(I)
      AML(I,9)=-0.625*WZ(I)*L(I)
      AML(I,5)=0.0
      AML(I,11)=-0.125*WZ(I)*L(I)*L(I)
      GO TO 1350
 1330 AML(I,3)=-0.625*WZ(I)*L(II
      AML(I,9)=-0.375*WZ(I)*L(I)
      AML(I,5)=0.125*WZ(II*L(I)*L(I)
      AML(I,11)=0.0
 1350 CONTINUE
```

```
      IF(IZ1.EQ.1.AND.IZ2.EQ.1) GO TO 1410
      IF(IZ1.EQ.1.AND.IZ2.EQ.0) GO TO 1420
      IF(IZ1.EQ.0.AND.IZ2.EQ.1) GO TO 1430
      GO TO 1450
 1410 AML(I,6)=0.0
      AML(I,12)=0.0
      GO TO 1450
 1420 AML(I,2)=-0.375*WY(I)*L(I)
      AML(I,8)=-0.625*WY(I)*L(I)
      AML(I,6)=0.0
      AML(I,12)=0.125*WY(I)*L(I)*L(I)
      GO TO 1450
 1430 AML(I,2)=-0.625*WY(I)*L(I)
      AML(I,8)=-0.375*WY(I)*L(I)
      AML(I,6)=-0.125*WY(I)*L(I)*L(I)
      AML(I,12)=0.0
 1450 CONTINUE
      AE(J1)=AE(J1)-R(I,1)*AML(I,1)-R(I,4)*AML(I,2)-R(I,7)*AML(I,3)
      AE(J2)=AE(J2)-R(I,2)*AML(I,1)-R(I,5)*AML(I,2)-R(I,8)*AML(I,3)
      AE(J3)=AE(J3)-R(I,3)*AML(I,1)-R(I,6)*AML(I,2)-R(I,9)*AML(I,3)
      AE(J4)=AE(J4)-R(I,1)*AML(I,4)-R(I,4)*AML(I,5)-R(I,7)*AML(I,6)
      AE(J5)=AE(J5)-R(I,2)*AML(I,4)-R(I,5)*AML(I,5)-R(I,8)*AML(I,6)
      AE(J6)=AE(J6)-R(I,3)*AML(I,4)-R(I,6)*AML(I,5)-R(I,9)*AML(I,6)
      AE(K1)=AE(K1)-R(I,1)*AML(I,7)-R(I,4)*AML(I,8)-R(I,7)*AML(I,9)
      AE(K2)=AE(K2)-R(I,2)*AML(I,7)-R(I,5)*AML(I,8)-R(I,8)*AML(I,9)
      AE(K3)=AE(K3)-R(I,3)*AML(I,7)-R(I,6)*AML(I,8)-R(I,9)*AML(I,9)
      AE(K4)=AE(K4)-R(I,1)*AML(I,10)-R(I,4)*AML(I,11)-R(I,7)*AML(I,12)
      AE(K5)=AE(K5)-R(I,2)*AML(I,10)-R(I,5)*AML(I,11)-R(I,8)*AML(I,12)
      AE(K6)=AE(K6)-R(I,3)*AML(I,10)-R(I,6)*AML(I,11)-R(I,9)*AML(I,12)
      IF(ICOUNT.GT.1) GO TO 218
      LOADX=LOADX-R(I,1)*(AML(I,1)+AML(I,7))-R(I,4)*(AML(I,2)+AML(I,8))-
     1R(I,7)*(AML(I,3)+AML(I,9))
      LOADY=LOADY-R(I,2)*(AML(I,1)+AML(I,7))-R(I,5)*(AML(I,2)+AML(I,8))-
     1R(I,8)*(AML(I,3)+AML(I,9))
      LOADZ=LOADZ-R(I,3)*(AML(I,1)+AML(I,7))-R(I,6)*(AML(I,2)+AML(I,8))-
     1R(I,9)*(AML(I,3)+AML(I,9))
  218 CONTINUE
  217 CONTINUE
C
C     CALCULATE AND OUTPUT RESULTS
C
      CALL SOLVE        (MTOT,MBAND,NEQ,    NJ,NUMEL,LL,NEQB,NBLOCK)       *
C
      NJ6=6*NJ
      IF(IPR.EQ.0.OR.IPLAS.EQ.0) GO TO 785
      MPRINT=0
      DO 226 JE=6,NJ6,6
      JE6=JE/6
      IF(MPRINT.NE.0) GO TO 6
      PRINT 3003
      PRINT 308
  308 FORMAT(20H JOINT DISPLACEMENTS,/,66H JOINT    X TRANS.    Y TRANS.    Z
     1TRANS.    X ROTA.    Y ROTA.    Z ROTA. )
      MPRINT=50
```

```
    6 MPRINT=MPRINT-1
      JEP=JE-5
      JE2=JE
      PRINT 256, JE6,(DJ(J),J=JEP,JE2)
  256 FORMAT(I5,6F10•6)
  226 CONTINUE
785   CONTINUE
C
C    BY-PASS IF NO BEAM ELEMENTS
      IF(M•LE•0) GO TO 504
C
C
C     COMPUTE STRESSES,BEAM ELEMENTS
C
      REWIND 18
      REWIND 15
      DO 914 I=1,M
      READ(18) (C(J),J=1,144)
      I11=2•I-1
      I12=2•I
      SIGBMX(I11)=0.0
      SIGBMX(I12)=0.0
      SIGMAX(I11)=0.0
      SIGMAX(I12)=0.0
      RK(1)=C(1)
      RK(2)=C(7)
      RK(3)=C(14)
      RK(4)=C(18)
      RK(5)=C(20)
      RK(6)=C(24)
      RK(7)=C(27)
      RK(8)=C(29)
      RK(9)=C(33)
      RK(10)=C(35)
      RK(11)=C(40)
      RK(12)=C(46)
      RK(13)=C(51)
      RK(14)=C(53)
      RK(15)=C(57)
      RK(16)=C(59)
      RK(17)=C(62)
      RK(18)=C(66)
      RK(19)=C(68)
      RK(20)=C(72)
      RK(21)=C(73)
      RK(22)=C(79)
      RK(23)=C(86)
      RK(24)=C(90)
      RK(25)=C(92)
      RK(26)=C(96)
      RK(27)=C(99)
      RK(28)=C(101)
      RK(29)=C(105)
      RK(30)=C(107)
      RK(31)=C(112)
      RK(32)=C(118)
      RK(33)=C(123)
      RK(34)=C(125)
      RK(35)=C(129)
      RK(36)=C(131)
      RK(37)=C(134)
      RK(38)=C(138)
      RK(39)=C(140)
      RK(40)=C(144)
      J1=6*JJ(1)-5
      J2=6*JJ(1)-4
      J3=6*JJ(1)-3
      J4=6*JJ(1)-2
      J5=6*JJ(1)-1
      J6=6*JJ(1)
      K1=6*JK(1)-5
      K2=6*JK(1)-4
      K3=6*JK(1)-3
      K4=6*JK(1)-2
      K5=6*JK(1)-1
      K6=6*JK(1)
  912 CONTINUE
C    DISPLACEMENTS IN LOCAL COORDINATES
      DJ1=DJ(J1)*R(1,1)+DJ(J2)*R(1,2)+DJ(J3)*R(1,3)
      DJ2=DJ(J1)*R(1,4)+DJ(J2)*R(1,5)+DJ(J3)*R(1,6)
      DJ3=DJ(J1)*R(1,7)+DJ(J2)*R(1,8)+DJ(J3)*R(1,9)
      DJ4=DJ(J4)*R(1,1)+DJ(J5)*R(1,2)+DJ(J6)*R(1,3)
      DJ5=DJ(J4)*R(1,4)+DJ(J5)*R(1,5)+DJ(J6)*R(1,6)
      DJ6=DJ(J4)*R(1,7)+DJ(J5)*R(1,8)+DJ(J6)*R(1,9)
      DK1=DJ(K1)*R(1,1)+DJ(K2)*R(1,2)+DJ(K3)*R(1,3)
      DK2=DJ(K1)*R(1,4)+DJ(K2)*R(1,5)+DJ(K3)*R(1,6)
      DK3=DJ(K1)*R(1,7)+DJ(K2)*R(1,8)+DJ(K3)*R(1,9)
      DK4=DJ(K4)*R(1,1)+DJ(K5)*R(1,2)+DJ(K6)*R(1,3)
      DK5=DJ(K4)*R(1,4)+DJ(K5)*R(1,5)+DJ(K6)*R(1,6)
      DK6=DJ(K4)*R(1,7)+DJ(K5)*R(1,8)+DJ(K6)*R(1,9)
C  COMPUTE MEMBER FORCES
      AMR(1)=RK(1)*DJ1+RK(2)*DK1
      AMR(2)=RK(3)*DJ2+RK(4)*DJ6+RK(5)*DK2+RK(6)*DK6
      AMR(3)=RK(7)*DJ3+RK(8)*DJ5+RK(9)*DK3+RK(10)*DK5
      AMR(4)=RK(11)*DJ4+RK(12)*DK4
      AMR(5)=RK(13)*DJ3+RK(14)*DJ5+RK(15)*DK3+RK(16)*DK5
      AMR(6)=RK(17)*DJ2+RK(18)*DJ6+RK(19)*DK2+RK(20)*DK6
      AMR(7)=RK(21)*DJ1+RK(22)*DK1
      AMR(8)=RK(23)*DJ2+RK(24)*DJ6+RK(25)*DK2+RK(26)*DK6
      AMR(9)=RK(27)*DJ3+RK(28)*DJ5+RK(29)*DK3+RK(30)*DK5
      AMR(10)=RK(31)*DJ4+RK(32)*DK4
      AMR(11)=RK(33)*DJ3+RK(34)*DJ5+RK(35)*DK3+RK(36)*DK5
      AMR(12)=RK(37)*DJ2+RK(38)*DJ6+RK(39)*DK2+RK(40)*DK6
      AMR(1)=AMR(1)+AML(1,1)
      AMR(2)=AMR(2)+AML(1,2)
      AMR(3)=AMR(3)+AML(1,3)
      AMR(4)=AMR(4)+AML(1,4)
      AMR(5)=AMR(5)+AML(1,5)
      AMR(6)=AMR(6)+AML(I,6)
      AMR(7)=AMR(7)+AML(I,7)
      AMR(8)=AMR(8)+AML(I,8)
      AMR(9)=AMR(9)+AML(I,9)
      AMR(10)=AMR(10)+AML(I,10)
      AMR(11)=AMR(11)+AML(I,11)
      AMR(12)=AMR(12)+AML(I,12)
      WRITE(15),(AMR(K),K=1,12)
C  COMPUTE STRESSES AT BOTH BEAM ENDS
      XM=0.0
      DO 10 K=1,2
      IF(K.EQ.2) XM=L(I)
      KK=I*2-2+K
      SIGAX(KK)=-AMR(1)/AX(I)
      IF(ABS(AMR(7)).GT.ABS(AMR(1))) SIGAX(KK)=AMR(7)/AX(I)
      MY=-AMR(3)*XM-AMR(5)-WZ(I)*XM**2/2.
      MZ=AMR(2)*XM-AMR(6)+WY(I)*XM**2/2.
      ICOR=1
      IF(TYPEM(I).EQ.6) ICOR=4
      DO 971 JOE=1,ICOR
      SIGBZ=-MZ*ACZ(I,JOE)/IZ(I)
      SIGBY=MY*ACY(I,JOE)/IY(I)
      SIGB=SIGBZ+SIGBY
      SIGMX=SIGB+SIGAX(KK)
      IF(TYPEM(I).EQ.6.AND.ABS(SIGMX).GT.ABS(SIGMAX(KK)))SIGMAX(KK)=SIGM
     1X
      IF(TYPEM(I).NE.6)SIGB=ABS(SIGBZ)+ABS(SIGBY)
      IF(TYPEM(I).EQ.3.OR.TYPEM(I).EQ.5)SIGB=SQRT(SIGBY**2+SIGBZ**2)
971   IF(ABS(SIGB).GT.ABS(SIGBMX(KK))) SIGBMX(KK)=SIGB
      IF(TYPEM(I).NE.6.AND.SIGAX(KK).LT.0)SIGBMX(KK)=-SIGBMX(KK)
      IF(TYPEM(I).EQ.6.AND.SIGAX(KK).GT.0.0.AND.SIGBMX(KK).LT.0.0) SIGBM
     1X(KK)=-SIGBMX(KK)
      IF(TYPEM(I).EQ.6.AND.SIGAX(KK).LT.0.AND.SIGBMX(KK).GT.0) SIGBMX(KK
     1)=-SIGBMX(KK)
      TAUMAX(KK)=AMR(4)*ACX(I)/IX(I)
      IF(TYPEM(I).NE.6) SIGMAX(KK)=SIGBMX(KK)+SIGAX(KK)
      SIGMAX(KK)=SIGBMX(KK)+SIGAX(KK)
      RADIUS=ABS(SQRT(TAUMAX(KK)**2+(SIGMAX(KK)/2.0)**2))
      SIGMA1(KK)=SIGMAX(KK)/2.0+RADIUS
      SIGMA2(KK)=SIGMAX(KK)/2.0-RADIUS
      VMISES=SQRT(0.5*(SIGMA1(KK)**2+SIGMA2(KK)**2+(SIGMA1(KK)-SIGMA2(KK
     1))**2))
      VMOY(KK)=VMISES/(YSTRS(I)*BM(I))
10    CONTINUE
914   CONTINUE
C
C     DETERMINE LOCATION OF PLASTIC HINGE
C
      RATIOL=5000000.0
      DO 8220 K=1,M2
      IF(IPL(K).GE.1) GO TO 8220
      IF(VMOY2(K).GE.1.0) GO TO 8220
      IF(VMOY(K).LT.0.00000)) GO TO 8220
      RATIO=(1.0-VMOY2(K))/VMOY(K)
      IF(RATIO.LT.RATIOL) MPL(ICOUNT)=K
      IF(RATIO.LT.RATIOL) RATIOL=RATIO
 8220 CONTINUE
C
C
C    INSERT MULTIPLE HINGES
      RATIOS=0.0
      IRCT=0
      RATIOT=RATIOL*1.05
      DO 8225 IQ=1,M2
      IF(IPL(IQ).GE.1) GO TO 8225
      RATIO=(1.0-VMOY2(IQ))/VMOY(IQ)
      VMOY3=VMOY2(IQ)+VMOY(IQ)*RATIOL
      IF(VMOY3.GT.0,99) GO TO 8325
      IF(RATIO.GT.RATIOT) GO TO 8225
 8325 IRCT=IRCT+1
      RATIOS=RATIOS+RATIO
      IPL(IQ)=ICOUNT
 8225 CONTINUE
      RATIOL=RATIOS/IRCT
      FACTOR(ICOUNT)=RATIOL
C
C    CHECK DEFLECTION LIMITATION FOR PLASTIC RUNS
      IF(IPLAS.NE.1) GO TO 552
      DEF(ICOUNT)=DJ(NOD6)
      IF(JOINT.EQ.0) DEF(ICOUNT)=0.0
      OJP1=ABS(OJP(NOD6))
      OJP2=OJP1+ABS(DJ(NOD6))*FACTOR(ICOUNT)
      ADLIM=ABS(DLIMIT)
      IF(IPLAS.EQ.1.ANO.ADLIM.GT.0.00001) GO TO 562
      XMAXL=0.0
      DO 5621 K=1,M
 5621 IF(L(K).GT.XMAXL) XMAXL=L(K)
      XMAXL2=XMAXL
      DO 5622 LT=1,NJ
      IF(ABS(DJ(LT*6-5)).GT.XMAXL2) ISTOP=1
      IF(ABS(DJ(LT*6-4)).GT.XMAXL2) ISTOP=1
      IF(ABS(DJ(LT*6-3)).GT.XMAXL2) ISTOP=1
      IF(ABS(DJ(LT*6-2)).GT.1.0) ISTOP=1
      IF(ABS(OJ(LT*6-1)).GT.1.0) ISTOP=1
 5622 IF(ABS(OJ(LT*6)).GT.1.0) ISTOP=1
      IF(ISTOP.EQ.1) FACTOR(ICOUNT)=0.0
      GO TO 552
 562  CONTINUE
      OJP1=ABS(DJP(NOD6))
      DJP2=OJP1+ABS(DJ(NOD6))*FACTOR(ICOUNT)
      IF(DJP2.LT.ADLIM) GO TO 552
      XX=(ADLIM-DJP1)/(OJP2-DJP1)
      FACTOR(ICOUNT)=FACTOR(ICOUNT)*XX
      ISTOP=1
 552  CONTINUE
      IF(ISTOP.EQ.1) IPR=1
C
C    UPDATE TOTAL OEFLECTION ARRAY
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      DO 550 KE=6,NJ6,6
      KF6=KE/6
      DO 550 K=1,6
      KP=KE-6+K
550   DJP(KP)=DJP(KP)+DJ(KP)*FACTOR(ICOUNT)
      IF(ISTOP.EQ.0) GO TO 3452
      MPRINT=0
      DO 426 JE=6,NJ6,6
      JE6=JE/6
      IF(MPRINT.NE.0) GO TO 61
      PRINT 3003
      PRINT 308
      MPRINT=50
61    MPRINT=MPRINT-1
      JEP=JE-5
      JE2=JE
      PRINT 256,JE6,(DJP(J),J=JEP,JE2)
426   CONTINUE
3452  CONTINUE
      IF(NUMPL.EQ.0) GO TO 8430
      IF(IPLAS.EQ.1.AND.ISTOP.NE.1) GO TO 8430
      REWIND 2
      DO 8420 IB=1,NBLOCK
      IA=(NBLOCK-IB)*NEQB+1
      IAA=IA+NEQB-1
8420  WRITE(2) (DJP(KA),KA=IA,IAA)
8430  CONTINUE
C
C   RATIO MEMBER STRESS ARRAYS AND UPDATE CUMULATIVE
C   MEMBER STRESS ARRAYS
C
      DO 8221 I=1,M2
      VMOY(I)=VMOY(I)*FACTOR(ICOUNT)
      VMOY2(I)=VMOY2(I)+VMOY(I)
      SIGAX(I)=SIGAX(I)*FACTOR(ICOUNT)
      SIGBMX(I)=SIGBMX(I)*FACTOR(ICOUNT)
      TAUMAX(I)=TAUMAX(I)*FACTOR(ICOUNT)
      SIGMAX(I)=SIGMAX(I)*FACTOR(ICOUNT)
      SIGMA1(I)=SIGMA1(I)*FACTOR(ICOUNT)
8221  SIGMA2(I)=SIGMA2(I)*FACTOR(ICOUNT)
      DO 9221 I=1,M2
      PSIGAX(I)=PSIGAX(I)+SIGAX(I)
      PSIGBM(I)=PSIGBM(I)+SIGBMX(I)
      PTAUMX(I)=PTAUMX(I)+TAUMAX(I)
      PSIGMX(I)=PSIGMX(I)+SIGMAX(I)
      PSIGM1(I)=PSIGM1(I)+SIGMA1(I)
9221  PSIGM2(I)=PSIGM2(I)+SIGMA2(I)
C
C     COMPUTE ENERGY FOR PLASTIC RUNS
      IF(IPLAS.NE.1) GO TO 8451
      ENERGY(ICOUNT)=0.0
      DO 8421 IEN=1,NJ
      IE1=IEN*6-5
      IE2=IEN*6-4
      IE3=IEN*6-3
      ENERGY(ICOUNT)=ENERGY(ICOUNT)+(A(IE1)+AE(IE1))*(0.5*FACTOR(ICOUNT)
     1+FACTOT)*DJ(IE1)*FACTOR(ICOUNT)+(A(IE2)+AE(IE2))*(0.5*FACTOR(ICOUN
     2T)+FACTOT)*DJ(IE2)*FACTOR(ICOUNT)+(A(IE3)+AE(IE3))*(0.5*FACTOR(ICO
     3UNT)+FACTOT)*DJ(IE3)*FACTOR(ICOUNT)
 8421 CONTINUE
      ENERGT=ENERGT+ENERGY(ICOUNT)
      FACTOT=FACTOT+FACTOR(ICOUNT)
 8451 CONTINUE
      DXMAXL=LOADX*FACTOR(ICOUNT)
      DYMAXL=LOADY*FACTOR(ICOUNT)
      DZMAXL=LOADZ*FACTOR(ICOUNT)
 504  CONTINUE
C
C    REACTIONS AT RESTRAINEO JOINTS
C
      NJ6=NJ*6
      MPRINT=0
      ICJ=0
      DO 450 KE=6,NJ6,6
      IF(MPRINT.NE.0) GO TO 8
      IF(IPR.EQ.1) PRINT 312
 312  FORMAT(1H1,///,31H REACTIONS AT RESTRAINED JOINTS,/,75H JOINT   X F
     1ORCE      Y FORCE      7 FORCE      X MOMENT     Y MOMENT     Z MOMENT)
 8    MPRINT=MPRINT+1
      KE6=KE/6
      KRL=0
      DO 460 K=1,6
      KP=KE-6+K
      REAC(K)=0.0
      IF(RL(KP).NE.1) GO 10 460
      KRL=1
      REAC(K)=-DJ(KP)*1.E20
 460  CONTINUE
      IF(KRL.NE.1) GO TO 450
      ICJ=ICJ+1
      DO 461 K=1,6
 461  REAC(K)=REAC(K)*FACTOR(ICOUNT)
      REAC1(ICJ)=REAC1(ICJ)+REAC(1)
      REAC2(ICJ)=REAC2(ICJ)+REAC(2)
      REAC3(ICJ)=REAC3(ICJ)+REAC(3)
      REAC4(ICJ)=REAC4(ICJ)+REAC(4)
      REAC5(ICJ)=REAC5(ICJ)+REAC(5)
      REAC6(ICJ)=REAC6(ICJ)+REAC(6)
      REACX=REACX+REAC(1)
      REACY=REACY+REAC(2)
      REACZ=REACZ+REAC(3)
      IF(IPR.EQ.1)
     *PRINT 2020,KE6,REAC1(ICJ),REAC2(ICJ),REAC3(ICJ),REAC4(ICJ),REAC5(I
     1CJ),REAC6(ICJ)
 450  CONTINUE
      DO 8226 I=1,M2
      IF(IPL(I).EQ.0) GO TO 8226
      MEMN=(I+1)/2
      MEMD=JJ(MEMN)
      IF((I/2-(I-1)/2).NE.0)MEMD=JK(MEMN)
      IF(RL(MEMD*6).EQ.1) RL(MEMD*6)=-1
      IF(RL(MEMD*6-1).EQ.1) RL(MEMD*6-1)=-1
      IF(RL(MEMD*6-2).EQ.1) RL(MEMD*6-2)=-1
 8226 CONTINUE
 2020 FORMAT(I5,6F12.1)
      IF(M.EQ.0) GO TO 508
      IF(IPR.EQ.0) GO TO 5082
      MPRINT=0
C
C    PRINT BEAM ELEMENT STRESSES
C
      IPRA=0
      DO 503 I=1,M2
      IF(MPRINT.NE.0)GO TO 13
      PRINT 3003
      PRINT 1313
      MPRINT=50
 13   MPRINT=MPRINT-1
      IMEM=(I+1)/2
      IMEMT=(I+1)/2-I/2
      NOD=JJ(IMEM)
      IF(IMEMT.EQ.0) NOD=JK(IMEM)
      VMISES=YSTRS(IMEM)*VMOY2(I)*BM(IMEM)
      IF(ABS(PSIGBM(I)).GT.YSTRS(IMEM))PSIGBM(I)=YSTRS(IMEM)*PSIGBM(I)/(
     1ABS(PSIGBM(I)))
      IF(ABS(PSIGMX(I)).GT.YSTRS(IMEM))PSIGMX(I)=YSTRS(IMEM)*PSIGMX(I)/(
     1ABS(PSIGMX(I)))
      IF(ABS(PSIGM1(I)).GT.YSTRS(IMEM))PSIGM1(I)=YSTRS(IMEM)*PSIGM1(I)/(
     1ABS(PSIGM1(I)))
      IF(ABS(PSIGM2(I)).GT.YSTRS(IMEM))PSIGM2(I)=YSTRS(IMEM)*PSIGM2(I)/(
     1ABS(PSIGM2(I)))
      IF(ABS(VMISES).GT.YSTRS(IMEM)) VMISES=YSTRS(IMEM)
      IF(VMOY2(I).GT.1.0) VMOY2(I)=1.0
      IF(ABS(PSIGAX(I)).GT.YSTRS(IMEM))IPRA=1
      PRINT 319,IMEM,NOD,PSIGBM(I),PSIGAX(I),PTAUMX(I),PSIGMX(I),
     1PSIGM1(I),PSIGM2(I),VMISES,VMOY2(I),IPL(I)
 503  CONTINUE
      IF(IPRA.EQ.1) PRINT 5182
 5182 FORMAT(//,'  * * AXIAL STRESS EXCEEDS YIELD, SEE SIGAX ABOVE')
 5082 CONTINUE
C
C    STORE UPDATED BEAM END REACTIONS ON TAPE 16
C
      REWIND 15
      REWIND 16
      REWIND 17
      DO 3681 IC=1,M
      IF(ICOUNT.GT.1) GO TO 3684
      NTP2=16
      READ(15),(AMR(I),I=1,12)
      DO 3687 ICT=1,12
 3687 AMR(ICT)=AMR(ICT)*FACTOR(ICOUNT)
```

```
      WRITE(16),(AMR(I),I=1,12)
      GO TO 3681
3684  ITAPE=(ICOUNT+1)/2-ICOUNT/2
      NTP1=16
      NTP2=17
      IF(ITAPE.EQ.1) NTP1=17
      IF(ITAPE.EQ.1) NTP2=16
      READ(15),(AMR(I),I=1,12)
      READ(NTP1),(AMR2(I),I=1,12)
      DO 3690 IO=1,12
3690  AMR2(IO)=AMR2(IO)+AMR(IO)*FACTOR(ICOUNT)
      WRITE(NTP2),(AMR2(I),I=1,12)
3681  CONTINUE
C
C    PRINT BEAM END REACTIONS
C
      IF(IPR.EQ.0) GO TO 508
      REWIND NTP2
      IPRINT=0
      DO 3693 IMP=1,M
      IF(IPRINT.NE.0) GO TO 97
      PRINT 98
      PRINT 96
      PRINT 95
      IPRINT=50
97    IPRINT=IPRINT-1
      READ(NTP2),(AMR(I),I=1,12)
      PRINT 99,IMP,(AMR(IV),IV=1,12)
3693  CONTINUE
95    FORMAT(' MEMBER    X FORCE    Y FORCE    Z FORCE    X MOMENT   Y MOMENT
     1   Z MOMENT     X FORCE     Y FORCE     Z FORCE     X MOMENT   Y MOMENT   Z
     2MOMENT')
96    FORMAT(36X7H J NODE,54X,7H K NODE)
98    FORMAT(1H1,' MEMBER END REACTIONS-MEMBER COORDINATE SYSTEM (J LESS
     1 THAN K)')
99    FORMAT(I5,2X,6F10.1,2X,6F10.1)
508   CONTINUE
1313  FORMAT(1H ,35X,16H MEMBER STRESSES,//,102H MEMBER   NODE   SIGBMX
     1  SIGAX     TAUMAX     SIGMAX     SIGMA1     SIGMA2     VMISES   VMISES/
     2ALLOW   HINGE )
319   FORMAT(I5,I7,7F10.0,F10.2,I8)
C
C *********   BEGINNING OF BUCKLING ADDITION   *********
C
C   THE BUCKLING MEMBER CONTROL NBM IS READ OFF THE FIRST DATA CARD
C
C       FROM HERE TO STATEMENT 71 IS BYPASSED IF THE NUMBER OF BUCKLING
C      MEMBERS(NBM) IS ZERO
C
      IF(ICOUNT.GT.1) GO TO 71
      IF(NBM)71,71,72
72    CALL BUCKLE(NBM,E,G,FACTOR(1))
      PRINT 3003
      PRINT 3005
```

```
 3005 FORMAT(1H ,15X,'BUCKLING RESULTS',///)
      PRINT 3007
 3007 FORMAT(1H ,59H  BUCKLING        END      P.GT.15%    MEMBER
     1AXIAL  ,/,105H    MEMBER       MEMBERS  P CRITICAL   BUCKLE
     1STRESS     SIGMA1     SIGMA2     VMISES    VMISES/YIELD )
      DO 975 KK=1,NBM
      SIGBMX(KK)=0.0
      I=N11(KK)
      IL=N12(KK)
      IS1=2*N11(KK)-1
      IS2=2*N12(KK)-1
      SIGAX1=SIGAX(IS1)
      SIGAX2=SIGAX(IS2)
      IF(IND1(KK).EQ.' NO') GO TO 973
      IF(IND2(KK).EQ.'YES,Y'.OR.IND2(KK).EQ.'YES,Z') GO TO 974
C
C     COMPUTE STRESS AT EACH INCREMENT OF THE BUCKLING MEMBER
C
      DO 972 K=1'NINCR
      ICOR=1
      IF(TYPEM(I).EQ.6)ICOR=4
      DO 1971 JOE=1,ICOR
      SIGBZ=-URMZ(KK,K)*ACZ(I,JOE)/IZ(I)
      SIGBY=URMY(KK,K)*ACY(I,JOE)/IY(I)
      SIGB=SIGBY+SIGBZ
      IF(TYPEM(I).EQ.6.AND.ABS(SIGB).GT.ABS(SIGBMX(KK)))SIGBMX(KK)=SIGB
      IF(TYPEM(I).NE.6)SIGB=ABS(SIGBZ)+ABS(SIGBY)
      IF(TYPEM(I).EQ.3.OR.TYPEM(I).EQ.5)SIGB=SQRT(SIGBY**2+SIGBZ**2)
 1971 IF(ABS(SIGB).GT.ABS(SIGBMX(KK)))SIGBMX(KK)=SIGB
  972 CONTINUE
      SIGBMX(KK)=-SIGBMX(KK)
      IF(TYPEM(I).NE.6) SIGMAX(KK)=SIGBMX(KK)+SIGAX1
      SIGMAX(KK)=SIGBMX(KK)+SIGAX1
      RADIUS=ABS(SQRT(TAUMAX(IS1)**2+(SIGMAX(KK)/2.)**2))
      SIGMA1(KK)=SIGMAX(KK)/2.0+RADIUS
      SIGMA2(KK)=SIGMAX(KK)/2.0-RADIUS
      VMISES=SQRT(0.5*(SIGMA1(KK)**2+SIGMA2(KK)**2+(SIGMA1(KK)-SIGMA2
     1(KK))**2))
      VMOY(KK)=VMISES/YSTRS(I)
      PAXIAL=AMIN1(SIGAX1,SIGAX2)
      PRINT 7720,KK,N11(KK),N12(KK),IND1(KK),IND2(KK),PAXIAL,SIGMA1(KK),
     1SIGMA2(KK),VMISES,VMOY(KK)
      AXFBM=ABS(SIGAX1)*AX(I)
      IF(VMOY(KK).GT.1.0001) PRINT 7742
      IF(AXFBM.GT.YSTRS(I)) PRINT 7741
      GO TO 975
  973 PRINT 7730,KK,N11(KK),N12(KK),IND1(KK)
      GO TO 975
  974 PRINT 7740,KK,N11(KK),N12(KK),IND1(KK),IND2(KK)
  975 CONTINUE
   71 CONTINUE
C
C *********  END OF BUCKLING ADDITION  *********
C
```

```
 7701 FORMAT(I5)
 7720 FORMAT(1H ,5X,I2,8X,I2,2X,I2,7X,A3,8X,A5,4X,4F10.0,F10.2)
 7730 FORMAT(1H ,5X,I2,8X,I2,2X,I2,7X,A3)
 7740 FORMAT(1H ,5X,I2,8X,I2,2X,I2,7X,A3,8X,A5)
 7741 FORMAT(' * * AXIAL STRESS EXCEEDS YIELD IN ABOVE BUCKLING MEMBER')
 7742 FORMAT(' * * CROSS SECTION HAS STARTED TO YIELD IN ABOVE BUCKLING
     1MEMBER')
C     PRINT OUT STRESSES IN SHELL MEMBERS
C
C
C   UPDATE JOINT COORDINATES FOR DEFORMED PLOTS
C
      IF(IPLOTD.NE.1) GO TO 8327
      DO 8320 J=1,NJ
      IN1=J*6-5
      IN2=J*6-4
      IN3=J*6-3
      XP(J)=XP(J)+DJ(IN1)*FACTOR(ICOUNT)*DMAG
      YP(J)=YP(J)+DJ(IN2)*FACTOR(ICOUNT)*DMAG
 8320 ZP(J)=ZP(J)+DJ(IN3)*FACTOR(ICOUNT)*DMAG
 8327 CONTINUE
      N2=N1+4*LL
      N3=N2+NEQB*LL
      LB=(MTOT-N3)/(NEQ+12)
      IF(NUMPL.EQ.0) GO TO 1150
      IF(IPLAS.NE.1.OR.ISTOP.EQ.1)
C
C     COMPUTE PLATE ELEMENT STRESSES
C
     *CALL STRESS(C(N1),C(N2),C(N3),NEQB,LB,LL,NEQ,NBLOCK)
 1150 CONTINUE
      IF(IPR.EQ.0) GO TO 284
      PRINT 3003
      PRINT 280,LOADX,LOADY,LOADZ
 280  FORMAT(///,'    INPUT LOADS,GLOBAL COORDINATE SYSTEM',//,
     1     '         X DIRECTION:',F8.0,' POUNDS',/,
     2     '         Y DIRECTION:',F8.0,' POUNDS',/,
     3     '         Z DIRECTION:',F8.0,' POUNDS',///)
      PRINT 4315,REACX,REACY,REACZ
 4315 FORMAT(55H MAXIMUM LOAD THAT CANOPY CAN SUPPORT IN X DIRECTION IS,
     1        F8.0,8H  POUNDS,/,
     2        55H MAXIMUM LOAD THAT CANOPY CAN SUPPORT IN Y DIRECTION IS,
     3        F8.0,8H  POUNDS,/,
     4        55H MAXIMUM LOAD THAT CANOPY CAN SUPPORT IN Z DIRECTION IS,
     5        F8.0,8H  POUNDS)
      WPL=VTPL*.2836
      WBPP=WPL+WGTC
      PRINT 476,WGTC,WPL,WBPP
 476  FORMAT(//,'     WEIGHT OF BEAM ELEMENTS  =',F5.0,' POUNDS',/,
     1  '     WEIGHT OF PLATE ELEMENTS =',F5.0,' POUNDS',/,
     2  '     TOTAL CANOPY WEIGHT      =',F5.0,' POUNDS')
 284  CONTINUE
      REWIND 8
      REWIND 18
      IF(IPLAS.EQ.1.AND.ISTOP.NE.1) GO TO 945
C
C    CALL PLOT ROUTINES
C
      IF)IPLOTI.EQ.0.AND.IPLOTD.EQ.0) GO TO 3588
      DO 3598 NPL=1,NVIEW
      ANGL)1)='THETA='
      ANGL)3)='  PHI='
      IF)IANGLE.EQ.0.AND.NVIEW.EQ.1) GO TO 3142
      READ 92,THETA,PHI
      READ(0,992) ANGL)2),ANGL)4)
992   FORMAT(2A6)
      GO TO 3144
3142  ANGL(2)=' 120.0'
      ANGL)4)='  30.0'
3144  IF(IPLOTI.EQ.1)
     *CALL PLOTS(0,NJ,M,NUMPL,X,Y,Z,JJ,JK,THETA,PHI,TITLE,ANGL)
      ISFT=1
      IF)IPLOTI.EQ.0.OR.ISHIFT.EQ.1) ISFT=0
      IF(IPLOTD.EQ.1)
     *CALL PLOTS)ISFT,NJ,M,NUMPL,XP,YP,ZP,JJ,JK,THETA,PHI,TITLE,ANGL)
3598  CONTINUE
3588  CONTINUE
92    FORMAT)2F6.1)
      IF(IPLAS.NE.1) GO TO 1216
      PRINT 3003
      PRINT 800
800   FORMAT)////,'               * * *   P L A S T I C   A N A L Y S I
     1S   S U M M A R Y ')
      ELX=LOADX*FACTOR)1)
      ELY=LOADY*FACTOR)1)
C
C     PRINT PLASTIC ANALYSIS SUMMARY
C
      ELZ=LOADZ*FACTOR(1)
      REX=-1.0*REACX
      REY=-1.0*REACY
      REZ=-1.0*REACZ
      PRINT 810,ELX,ELY,ELZ,REX,REY,REZ
810   FORMAT)////,'     APPLIED LOADS AT ELASTIC LIMIT: F)X)=',F8.0,/,
     1            '                                     F)Y)=',F8.0,/,
     2            '                                     F)Z)=',F8.0,//,
     3            '     APPLIED LOADS AT ULTIMATE:      F)X)=',F8.0,/,
     4            '                                     F(Y)=',F8.0,/,
     5            '                                     F(Z)=',F8.0)
      PEN=0.0
      PLDX=0.0
      PLDY=0.0
      PLDZ=0.0
      PDEF =0.0
      ADIREC='  '
      IF(IDIREC.EQ.1) ADIREC=' X'
      IF(IDIREC.EQ.2) ADIREC=' Y'
      IF(IDIREC.EQ.3) ADIREC=' Z'
      PRINT 820,JOINT,ADIREC
      DO 1820 KE=1,ICOUNT
      PLDX=PLDX+LOADX*FACTOR(KE)
      PLDY=PLDY+LOADY*FACTOR(KE)
      PLDZ=PLDZ+LOADZ*FACTOR(KE)
      PDEF=PDEF+DEF(KE)*FACTOR(KE)
      PEN=PEN+ENERGY(KE)
1820  PRINT 830,KE,PLDX,PLDY,PLDZ,PDEF,PEN
830   FORMAT(5X,I2,6X,F8.0,3X,F8.0,3X,F8.0,9X,F8.4,16X,F9.0)
82D   FORMAT(///,20X,'LOADING SUMMARY',//,4X,'LOAD',11X,'APPLIED LOADS (
     1LBS)',8X,'DEFLECTION,INCHES,NODE',I3,5X,'ENERGY (IN-LB)',/,2X,'INC
     2REMENT',5X,'F(X)',7X,'F(Y)',7X,'F(Z)',5X,'GLOBAL',A2,' DIRECTION')
1216  CONTINUE
      NLS=NLS-1
      IF(NLS.EQ.0) GO TO 946
C
C     ZERO ARRAYS FOR NEXT LOADING CASE
C
      FACTOR(1)=1.0
      ILOAD=1
      ICOUNT=0
      LMLT=0
      ISTOP=0
      IPR=0
      ENERGT=0.0
      FACTOT=0.0
      REACX=0.0
      REACY=0.0
      REACZ=0.0
      DO 1960 LI=1,200
      PSIGAX(LI)=0.0
      PSIGBM(LI)=0.0
      PTAUMX(LI)=0.0
      PSIGMX(LI)=0.0
      PSIGM1(LI)=0.0
      PSIGM2(LI)=0.0
      IPL(LI)=0
      VMOY(LI)=0.0
1960  VMOY2(LI)=0.0
      DO 1970 LJ=1,20
      REAC1(LJ)=0.0
      REAC2(LJ)=0.0
      REAC3(LJ)=0.0
      REAC4(LJ)=0.0
      REAC5(LJ)=00.0
1970  REAC6(LJ)=0.0
      DO 1980 LK=1,600
      DJP(LK)=0.0
      A(LK)=0.0
      AE(LK)=0.0
1980  RL(LK)=ABS(RL(LK))
      DO 1990 LL=1,M
      BM(LL)=PBM(LL)
      WX(LL)=0.0
      WY(LL)=0.0
      WZ(LL)=0.0
      LML(LL)=0
      DO 1990 LAI=1,12
 1990 AML(LL,LAI)=0.0
      GO TO 945
  946 CONTINUE
      IF(NST.GT.1) GO TO 944
      GO TO 1500
 1492 PRINT 1494
 1494 FORMAT(1H1,60H TOO MANY UNKNOWN DISPLACEMENTS. REDIMENSION STIFFNE
     1SS ARRAY )
 1500 CONTINUE
      IF(IFINV.EQ.1) CALL FINSHV
      STOP
      END
      SUBROUTINE PROP
C**********************************************************************
C     SUBROUTINE TO COMPUTE SECTION PROPERTIES FOR MEMBERS
C**********************************************************************
      COMMON/MPROP/AXP,IXP,IYP,IZP,ACXP,ACYP,ACZP,FP,H,B,TW,TF,TYPES,BRC
      REAL IXP,IYP,IZP
      INTEGER TYPES
      PI=3.141592653
      GO TO(1,2,3,4,5), TYPES
    1 AXP=(H-2.*TF)*TW+2.*B*TF
      FP=AXP/((H-TF)*TW)
      IYP=B**3*TF/6.+TW**3*(H-2.*TF)/12.
      IZP=2.*TF*B*((H-TF)/2.)**2+B*TF**3/6.+TW*(H-2.*TF)**3/12.
      IXP=((H-TF)*TW**3+2.*B*TF**3)/3.
      ACYP=B/2.
      ACZP=H/2.
      ACXP=TF
      PIZ=B*(H-TF)*TF+((H-2.0*TF)**2)*TW/4.0
      BRZ=PIZ/(IZP/ACZP)
      BRC=BRZ
      RETURN
    2 AXP=2.*(H-2.*TF)*TW+2.*(B-2.*TW)*TF
      FP1=AXP/(2.*TW*(H-TF))
      FP2=AXP/(2.*TF*(B-TW))
      FP=FP1
      IF(FP2.GT.FP1) FP=FP2
      IYP=TF*(B-2.*TW)**3/6.+2.*(H-2.*TF)*TW*((B-TW)/2.)**2
     1  +(H-2.*TF)*TW**3/6.
      IZP=TW*(H-2.*TF)**3/6.+2.*(B-2.*TW)*TF*((H-TF)/2.)**2
     1  +(B-2.*TW)*TF**3/6.
      IXP=2.*(B-TW)**2*(H-TF)**2*(TF*TW/((B-TW)*TW+(H-TF)*TF))
      ACYP=B/2.
      ACZP=H/2.
      T=TF
      IF(T.LT.TW) T=TW
      ACXP=IXP/(2.*(B-TW)*(H-TF)*T)
      PIY=(H-2.0*TF)*(B-TW)*TW+TF*0.5*(B-2.0*TW)**2
      PIZ=(B-2.0*TW)*(H-TF)*TF+TW*0.5*(H-2.0*TF)**2
      BRY=PIY/(IYP/ACYP)
      BRZ=PIZ/(IZP/ACZP)
      BRC=(BRY+BRZ)/2.0
      RETURN
    3 H=H/2.
      AXP=PI*(H**2-(H-TW)**2)
      FP=2.
      IXP=2.*PI*(H-TW/2.)**3*TW
      IYP=IXP/2.
      IZP=IYP
      ACXP=H
      ACYP=H
      ACZP=H
      PIY=((4.0/3.0)*TW*H)*(3.0*H-3.0*TW+TW*TW/H)
      BRC=PIY/(IYP/H)
      RETURN
    4 AXP=B*H
      FP=6./5.
      IYP=H*B**3/12.
      IZP=B*H**3/12.
      BETA=1./3.-0.21*(B/H)*(1.-B**4/(12.*H**4))
      IF(B.GT.H) BETA=1./3.-0.21*(H/B)*(1.-((H/B)**4/12.))
      IXP=BETA*H*B**3
      IF(B.GT.H) IXP=BETA*B*H**3
      ALPHA=.21597*(H/B)**.175
      IF(B.GT.H) ALPHA=.21597*(B/H)**.175
      IF(BETA.GT.0.263) ALPHA=BETA
      ACYP=B/2.
      ACZP=H/2.
      ACXP=(BETA/ALPHA)*B
      IF(B.GT.H) ACXP=BETA*H/ALPHA
      BRC=1.5
      RETURN
    5 H=H/2.
      AXP=PI*H**2
      FP=10./9.
      IYP=PI*H**4/4.
      IZP=IYP
      IXP=2.*IYP
      ACYP=H
      ACXP=H
      ACZP=H
      BRC=1.7
      RETURN
      END
      SUBROUTINE BEAM (JAK,SMR,MBAND)
      COMMON/EM/LM(24),ND,NS,S(24,24),P(24,4),XM(24),SA(12,24),TT(12,4)
      DIMENSION JAK(12),SMR(12,12)
C
      DO 10  I=1,1058
   10 LM(I) = 0
      DO 20  I=1,12
   20 LM(I) = JAK(I)
      DO 30  I=1,12
      DO 30  J=1,12
   30 S(I,J) = SMR(I,J)
      NS =12
      ND =12
      NDM=24
C
      CALL CALBAN (MBAND,NDIF,LM,XM,S,P,ND,NDM)
      RETURN
      END
      SUBROUTINE BOUND (ID,MBAND)
      COMMON/EM/LM(24),ND,NS,S(24,24),P(24,4),XM(24),SA(12,24),TT(12,4)
C
      DO 10  I=1,1058
   10 LM(I) = 0
C
      NS=1
      ND=1
      NDM=24
      LM(1) = ID
      S(1,1) = 1.E20
C
      CALL CALBAN (MBAND,NDIF,LM,XM,S,P,ND,NDM)
      RETURN
      END
      SUBROUTINE SOLVE (MTOT,MBAND,NEQ,NUMNP,NUMEL,LL,NEQB,NBLOCK)
      COMMON A(1)
C     RIGHT HAND SIDE               (ON TAPE 3)
      N1 = 1
      N2 = N1+NEQB*LL
      CALL INL (A(N1),NUMNP,NEQB,LL)
C
C     FORM TOTAL STIFFNESS MATRIX   (ON TAPE 4)
      NE2B=2*NEQB
      NN2=N1+NE2B*MBAND
      NN3=NN2+NE2B*LL
      CALL ADDSTF (A(N1),A(NN2),A(NN3),NUMEL,NBLOCK,NE2B,LL,MBAND)
C
      N2=N1+NEQB*MBAND
      N3=N2+NEQB*LL
      N4=N3+4*LL
C
C     SOLVE FOR DISPLACEMENT UNKNOWNS
      NSB=(MBAND+LL)*NEQB
      NSBB=NEQB*LL*(2+(MBAND-1)/NEQB)
      IF(NSBB.LT.NSB) NSBB=NSB
      N4=N3+NSBB
      CALL USOL (A(N1),A(N3),A(N4),NEQB,MBAND,LL,NBLOCK,NSB,4,3,7,2,2)
C
C     PRINT DISPLACEMENTS
      N2=N1+NEQB*LL
      CALL PRINTD (A(N1),NEQB,NUMNP,LL,NBLOCK,NEQ)
      RETURN
      END
      SUBROUTINE CALBAN(MBAND,NDIF,LM,XM,S,P,ND,NDM)
C
C-----CALCULATES BAND WIDTH AND WRITES STIFFNESS MATRIX ON TAPE 8
C
      DIMENSION LM(1),XM(1),S(NDM,NDM),P(NDM,4)
C
      MIN=100000                                                        QUAD 100
      MAX=0                                                             QUAD 101
C
      DO 800 L=1,ND                                                     QUAD 102
      IF (LM(L).EQ.0) GO TO 800                                         QUAD 103
      IF (LM(L).GT.MAX) MAX=LM(L)                                       QUAD 104
      IF (LM(L).LT.MIN) MIN=LM(L)                                       QUAD 105
  800 CONTINUE                                                          QUAD 106
C
      NDIF=MAX-MIN+1                                                    QUAD 107
      IF (NDIF.GT.MBAND) MBAND=NDIF                                     QUAD 108
C
      LRD=1+ND*(ND+6)                                                   QUAD 113
      WRITE (8) LRD,ND,(LM(I),I=1,ND),((S(I,J),I=1,ND),J=1,ND),         QUAD 115
     1 ((P(I,J),I=1,ND),J=1,4),(XM(I),I=1,ND)                           QUAD 116
      IF(LRD.GT.217)
     *WRITE(11) LRD,ND,(LM(I),I=1,ND),((S(I,J),I=1,ND),J=1,ND),((P(I,J),
     1I=1,ND),J=1,4),(XM(I),I=1,ND)
C
      RETURN
      END
      SUBROUTINE INL (B,NUMNP,NEQB,LL)
C
C     FORM RHS IN BLOCKS OF NEQB ON TAPE 3
C
      COMMON/LOADS/
     *          A(600),AML(100,12),LML(100),AE(600),AC(600),D(600)
      DIMENSION B(NEQB,LL)
C
      NT=3
      REWIND NT
      KSHF=0
      DO 750  I=1,NEQB
      DO 750  K=1,LL
  750 B(I,K)=0.0
C
      NUMEQ=6*NUMNP
      DO 800  NN=1,NUMEQ
      II=NN-KSHF
      IF(II.LE.0) GO TO 800
      DO 600  K=1,LL
  600 B(II,K) = A(NN)+AE(NN)
      IF(II.NE.NEQB) GO TO 800
      WRITE(NT) B
      KSHF=KSHF+NEQB
      DO 700  I=1,NEQB
      DO 700  K=1,LL
  700 B(I,K)=0.0
  800 CONTINUE
      WRITE(NT) B
      RETURN
      END
      SUBROUTINE ADDSTF (A,B,STR,NUMEL,NBLOCK,NE2B,LL,MBAND)
C
C     FORMS GLOBAL EQUILIBRIUM EQUATIONS IN BLOCKS                      ADDST   3
C
      DIMENSION A(NE2B,MBAND),B(NE2B,LL),STR(4,LL),SS(1)
C
      COMMON /EM/ LRD,ND,LM(1056)
C
      EQUIVALENCE (SS,NO)                                               ADDST   7
C
      NEQB=NE2B/2                                                       ADDST   8
      K=NEQB+1                                                          ADDST   9
      X=NBLOCK                                                          ADDST  10
      MB=SQRT(X)                                                        ADDST  11
      MB=MB/2+1                                                         ADDST  12
      NEBB=MB*NE2B                                                      ADDST  13
      MM=1                                                              ADDST  14
C                                                                       ADDST  15
      NSHIFT=0                                                          ADDST  16
      REWIND 3                                                          ADDST  17
      REWIND 4                                                          ADDST  18
C                                                                       ADDST  20
      DO 50  L=1,LL
      DO 50  I=1,4
   50 STR(I,L) = 1.0
C                                                                       ADDST  28
C     FORM EQUATIONS IN BLOCKS      ( 2 BLOCKS AT A TIME)               ADDST  29
C                                                                       ADDST  30
      DO 1000 M=1,NBLOCK ,2                                             ADDST  31
      DO 100 I=1,NE2B                                                   ADDST  32
      DO 100 J=1,MBAND                                                  ADDST  33
  100 A(I,J)=0.                                                         ADDST  34
      READ (3) ((B(I,L),I=1,NEQB),L=1,LL)
      IF (M.EQ.NBLOCK) GO TO 200                                        ADDST  36
      READ (3) ((B(I,L),I=K,NE2B),L=1,LL)
  200 CONTINUE                                                          ADDST  38
C                                                                       ADDST  39
      REWIND 7                                                          ADDST  40
      REWIND 8
      NA=7                                                              ADDST  42
      NUME=NUM7                                                         ADDST  43
      IF (MM.NE.1) GO TO 75                                             ADDST  44
      NA=8
      NUME=NUMEL                                                        ADDST  46
      NUM7 =0                                                           ADDST  47
C                                                                       ADDST  48
   75 DO 700 N=1,NUME                                                   ADDST  49
      READ (NA) LRD,(SS(I),I=1,LRD)                                     ADDST  50
      DO 600 I=1,NO                                                     ADDST  51
      LMN=I-LM(I)                                                       ADDST  52
      II=LM(I)-NSHIFT                                                   ADDST  53
      IF (II.LE.0.OR.II.GT.NE2B) GO TO 600                              ADDST  54
      DO 300 L=1,LL                                                     ADDST  57
      DO 300 J=1,4                                                      ADDST 58
      KK=ND*(ND+J)+1                                                    ADDST 59
  300 B(II,L)=B(II,L)+SS(I+KK)*STR(J,L)                                 ADDST 60
      DO 500 J=1,ND                                                     ADDST 61
      JJ=LM(J)+LMN                                                      ADDST 62
      IF(JJ) 500,500,390                                                ADDST 63
  390 KK=ND*J+1                                                         ADDST 64
  400 A(II,JJ)=A(II,JJ)+SS(I+KK)                                        ADDST 65
  500 CONTINUE                                                          ADDST 66
  600 CONTINUE                                                          ADDST 67
C                                                                       ADDST 68
C     DETERMINE IF STIFFNESS IS TO BE PLACED ON TAPE 7                  ADDST 69
C                                                                       ADDST 70
      IF (MM.GT.1) GO TO 700                                            ADDST 71
      DO 650 I=1,ND                                                     ADDST 72
      II=LM(I) -NSHIFT                                                  ADDST 73
      IF(II.GT.NE2B.AND.II.LE.NEBB) GO TO 660                           ADDST 74
  650 CONTINUE                                                          ADDST 75
      GO TO 700                                                         ADDST 76
  660 WRITE (7) LRD,(SS(I),I=1,LRD)                                     ADDST 77
      NUM7=NUM7+1                                                       ADDST 78
C                                                                       ADDST 79
  700 CONTINUE                                                          ADDST 80
      WRITE(4) ((A(I,J),I=1,NEQB),J=1,MBAND),((B(I,L),I=1,NEQB),L=1,LL) ADDST 81
      IF(M.EQ.NBLOCK) GO TO 1000                                        ADDST 83
      WRITE(4) ((A(I,J),I=K,NE2B),J=1,MBAND),((B(I,L),I=K,NE2B),L=1,LL) ADDST 84
      IF (MM.EQ.MB) MM=0                                                ADDST 86
      MM=MM+1                                                           ADDST 87
 1000 NSHIFT=NSHIFT+NE2B                                                ADDST 88
C                                                                       ADDST 89
      RETURN                                                            ADDST 90
C
C
      END                                                               ADDST 95
      SUBROUTINE USOL (A,B,MAXB,NEQB,MB,LL,NBLOCK,NSB,NORG,NBKS,NT1,    USOL   1
     .                                                       NT2,NRST)  USOL   2
      DIMENSION A(NSB),B(NSB),MAXB(NEQB)                                USOL   3
C-----------------------------------------------------------------------USOL   4
      NCOUNT = 0
      NC=MB+LL                                                          USOL   5
      NBR=(MB-1)/NEQB+1                                                 USOL   6
      INC=NEQB-1                                                        USOL   7
      NMB=NEQB*MB                                                       USOL   8
      N2=NT2                                                            USOL   9
      N1=NT1                                                            USOL  10
      REWIND NORG                                                       USOL  11
      REWIND NBKS                                                       USOL  12
C                                                                       USOL  13
C---- REDUCE EQUATIONS  BLOCK-BY-BLOCK ---------------------------------USOL  14
C                                                                       USOL  15
      DO 900 N=1,NBLOCK                                                 USOL  16
      IF (N.GT.1.AND.NBR.EQ.1) GO TO 110                                USOL  17
      IF (NBR.EQ.1) GO TO 105                                           USOL  18
      REWIND N1                                                         USOL  19
      REWIND N2                                                         USOL  20
  105 NI=N1                                                             USOL  21
      IF(N.EQ.1) NI=NORG                                                USOL  22
      READ (NI) A                                                       USOL  23
  110 DO 300 I=1,NEQB                                                   USOL  24
      D=A(I)                                                            USOL  25
      IF(D) 115,300,120                                                 USOL  26
  115 M=NEQB*(N-1)+I                                                    USOL  27
      PRINT 116,  M,D
  116 FORMAT (33H0SET OF EQUATIONS MAY BE SINGULAR   /                  USOL  29
     .  26H DIAGONAL TERM OF EQUATION   I8, 8H  EQUALS   1PE12.4)       USOL  30
      NCOUNT = NCOUNT + 1
      IF(NCOUNT.EQ.10) STOP
C                                                                       USOL  31
  120 II=I                                                              USOL  32
      DO 125 J=2,NC                                                     USOL  33
      II=II+NEQB                                                        USOL  34
  125 A(II)=A(II)/D                                                     USOL  35
C                                                                       USOL  36
      DO 130 J=1,NMB,NEQB                                               USOL  37
      IF (A(J).NE.0.) MAXB(I)=J                                         USOL  38
  130 CONTINUE                                                          USOL  39
C                                                                       USOL  40
      JL=I+1                                                            USOL  41
      IF (JL.GT.NEQB) GO TO 300                                         USOL  42
      II=I                                                              USOL  43
      DO 200 J=JL,NEQB                                                  USOL  44
      II=II+NEQB                                                        USOL  45
      IF(II.GT.NMB) GO TO 200                                           USOL  46
      C=A(II)                                                           USOL  47
      IF (C.EQ.0.0) GO TO 200                                           USOL  48
      C=C*A(I)                                                          USOL  49
C                                                                       USOL  50
```

```
      KK=J-I1                                                           USOL  51
      MAX=MAXB(I)                                                       USOL  52
      00 150 JJ=I1,MAX,NEQB                                             USOL  53
  150 A(JJ+KK)=A(JJ+KK)-C*A(JJ)                                         USOL  54
C                                                                       USOL  55
      KK=J +NMB                                                         USOL  56
      JJ=I+NMB                                                          USOL  57
      DO 175 L=1,LL                                                     USOL  58
      A(KK)=A(KK)-C*A(JJ)                                               USOL  59
      KK=KK+NEQB                                                        USOL  60
  175 JJ=JJ+NEQB                                                        USOL  61
  200 CONTINUE                                                          USOL  62
  300 CONTINUE                                                          USOL  63
      WRITE (NBKS) A,MAXB                                               USOL  64
C                                                                       USOL  65
C---- SUBSTITUTE INTO REMAINING EQUATIONS ----------------------------- USOL  66
C                                                                       USOL  67
      DO 800 NN=1,NBR                                                   USOL  68
      IF(N+NN.GT.NBLOCK) GO TO 800                                      USOL  69
      NI=N1                                                             USOL  70
      IF(N.EQ.1) NI=NORG                                                USOL  71
      IF(NN.EQ.NBR) NI=NORG                                             USOL  72
      READ (NI) B                                                       USOL  73
      IL=1+NN*NEQB*NEQB                                                 USOL  74
      DO 700 I=1,NEQB                                                   USOL  75
      I1=IL                                                             USOL  76
      DO 690 K=1,NEQB                                                   USOL  77
      IF (I1.GT.NMB) GO TO 690                                          USOL  78
      C=A(I1)                                                           USOL  79
      IF (C.EQ.0.0) GO TO 690                                           USOL  80
      C=C*A(K)                                                          USOL  81
      MAX=MAXB(K)                                                       USOL  82
C                                                                       USOL  83
      KK=I-I1                                                           USOL  84
      DO 640 JJ=I1,MAX,NEQB                                             USOL  85
  640 B(JJ+KK)=B(JJ+KK)-C*A(JJ)                                         USOL  86
C                                                                       USOL  87
      KK=I+NMB                                                          USOL  88
      JJ=K+NMB                                                          USOL  89
      DO 650 L=1,LL                                                     USOL  90
      B(KK)=B(KK)-C*A(JJ)                                               USOL  91
      KK=KK+NEQB                                                        USOL  92
  650 JJ=JJ+NEQB                                                        USOL  93
C                                                                       USOL  94
  690 I1=I1-INC                                                         USOL  95
  700 IL=IL+NEQB                                                        USOL  96
C                                                                       USOL  97
      IF(NBR.NE.1) GO TO 750                                            USOL  98
      00 740 I=1,NSB                                                    USOL  99
  740 A(I)=B(I)                                                         USOL 100
      GO TO 800                                                         USOL 101
  750 WRITE (N2) B                                                      USOL 102
  800 CONTINUE                                                          USOL 103
C                                                                       USOL 104
```

```
      M=N1                                                              USOL 105
      N1=N2                                                             USOL 106
  900 N2=M                                                              USOL 107
C                                                                       USOL 108
C---- BACKSUBSTITUTION - RESULTS ON TAPE NRST ----------------------     USOL 109
C                                                                       USOL 110
      LS=LL*NEQB                                                        USOL 111
      NEB=NEQB*(NBR+1)                                                  USOL 112
      NUM=NBR*NEQB                                                      USOL 113
      MAX=NEB*LL                                                        USOL 114
      DO 905 I=1,MAX                                                    USOL 115
  905 B(I)=0.                                                           USOL 116
      REWIND NRST                                                       USOL 117
C-----------------------------------------------------------------      USOL 118
      DO 1000 N=1,NBLOCK                                                USOL 119
      BACKSPACE NBKS                                                    USOL 120
      READ (NBKS) A,MAXB                                                USOL 121
      BACKSPACE NBKS                                                    USOL 122
      DO 910 L=1,LL                                                     USOL 123
      K=L*NEB                                                           USOL 124
      DO 910 J=1,NUM                                                    USOL 125
      I=K-NEQB                                                          USOL 126
      B(K)=B(I)                                                         USOL 127
  910 K=K-1                                                             USOL 128
C                                                                       USOL 129
      I=NMB                                                             USOL 130
      DO 920 L=1,LL                                                     USOL 131
      K=(L-1)*NEB                                                       USOL 132
      DO 920 J=1,NEQB                                                   USOL 133
      I=I+1                                                             USOL 134
      K=K+1                                                             USOL 135
  920 B(K)=A(I)                                                         USOL 136
C                                                                       USOL 137
      DO 955 I=1,NEQB                                                   USOL 138
      J=NEQB+1-I                                                        USOL 139
      MAX=MAXB(J)                                                       USOL 140
      IF (A(J).EQ.0.) GO TO 955                                         USOL 141
      DO 950 L=1,LL                                                     USOL 142
      KK=J+(L-1)*NEB                                                    USOL 143
      JJ=KK+1                                                           USOL 144
      IL=J+NEQB                                                         USOL 145
      C=B(KK)                                                           USOL 146
      DO 940 II=IL,MAX,NEQB                                             USOL 147
      C=C-A(II)*B(JJ)                                                   USOL 148
  940 JJ=JJ+1                                                           USOL 149
  950 B(KK)=C                                                           USOL 150
  955 CONTINUE                                                          USOL 151
C                                                                       USOL 152
      I=0                                                               USOL 153
      DO 960 L=1,LL                                                     USOL 154
      K=(L-1)*NEB                                                       USOL 155
      DO 960 J=1,NEQB                                                   USOL 156
      K=K+1                                                             USOL 157
      I=I+1                                                             USOL 158
  960 A(I)=B(K)                                                           USOL 159
C                                                                         USOL 160
      WRITE (NRST) (A(I),I=I,L5)                                          USOL 161
 1000 CONTINUE                                                            USOL 162
C-----------------------------------------------------------------------  USOL 163
      RETURN                                                              USOL 164
      END                                                                 USOL 165
      SUBROUTINE PRINTD (B,NEQB,NUMNP,LL,NBLOCK,NEQ)
      DIMENSION B(NEQB)
      COMMON/SOLN/
     *          DJ(600),AR(600),AMR(12),JAK(12),TITLE(20)                      *
C
      REWIND 2
C
      M=NEQ
      NN=NEQB*NBLOCK
      N=NUMNP
C
      DO 500  KK=1,NUMNP
      I=6
      DO 250  II=1,6
      IF(M.GT.NN) GO TO 150
      IF(M.EQ.0 ) GO TO 150
      READ (2) B
      NN=NN-NEQB
  150 K=M-NN
C     SET DISPLACEMENTS INTO DJ-ARRAY
      DJ(M) = B(K)
      M=M-1
  250 I=I-1
  500 N=N-1
      RETURN
      END
      SUBROUTINE TPLATE(NUMEL,X,Y,Z,NUMNP,MBAND,E,GNU,AREAT)
C                                                                       SHEL  35
      COMMON/PLOT/IC1(150),IC2(150),IC3(150),IC4(150)
      COMMON/QTSARG/                                                    SHEL  36
     1XX(5),YY(5),ZZ(5),HM(5),HP(5),CM(3,3),ALFA(3),HW(5),RHO(5,3),P(5) SHEL  37
     2, T(5),OT(5),SM(5,3),BM(5,3),TDIS(36),TROT(36),S(30,30),R(30)
      COMMON/EM/LM(24),ND,NS,ASA(24,24),RF(24,4),XM(24),SA(12,24)       SHEL  39
     1,SF(12,4),PF(24)
      DIMENSION X(1),Y(1),Z(1), C(12,1),IX(7),IY(7),EL(4),TLO(5,4)      ***
C                                                                       SHEL  43
      IY(5)=0
      IY(6)=1
      EL(3)=0.0
      EL(4)=0.0
      AREAT=0.0
      AREAP=0.0
      LL     = 4
      NDM    = 24
      MTYPE  = 6
      ISTOP  = 0
      NS     = 6
C     DEGREES OF FREEDOM PER NODE
      NPF    = 6
C     MID-SIDE NODES
      MID    = 0
C     GLOBAL REFERENCE FOR DISPLACEMENTS/ROTATIONS
      IDIS   = 0
      IROT   = 0
C
C *** ELASTIC CONSTANTS FOR ISOTROPIC MATERIAL
C     C( 7)      C( 8)      C( 9)=0    C(10)      C(11)=0    C(12)
C      C-XX       C-XY       C-XS       C-YY       C-YS       G-XY
      DO 10  N=1,12
   10 C( N,1) = 0.0
      C( 7,1) = E / (1-GNU*GNU)
      C( 8,1) = GNU * C(7,1)
      C(10,1) = C(7,1)
      C(12,1) = 0.5*E / (1+GNU)
C
C *** SET ELEMENT LOAD MULTIPLIER = 1 FOR LATERAL(PRESSURE) LOADING
C
      DO 11  I=1,5
      DO 11  J=1,4
   11 TLO(I,J) = 0.0
      TLO(1,1) = 1.0
C                                                                       SHEL  74
C *** READ AND PRINT OF ELEMENT DATA                                    SHEL  75
C                                                                       SHEL  76
      WRITE(10) NUMEL
C
      WRITE (6,2003)                                                    SHEL  77
      NN=0                                                              SHEL  78
  100 READ (5,1001) MM,(IY(I),I=1,4),IY(7),EL(1),EL(2)
  110 NN=NN+1                                                           SHEL  80
      IF (MM-NN) 440,50,60                                              SHEL  81
   50 DO 45 I=1,7                                                       SHEL  82
   45 IX(I)=IY(I)                                                       SHEL  83
      INCL=IY(7)                                                        SHEL  84
      IF (IY(6).EQ.0) IY(6)=1                                           SHEL  85
      IM=IY(6)                                                          SHEL  86
      IF(INCL.EQ.0) INCL=1                                              SHEL  87
      NNS=5                                                             SHEL  88
      IF (IY(5).EQ.0) NNS=4                                             SHEL  89
      IF (IY(4).EQ.0) NNS=3                                             SHEL  90
      RHOM=C(3,IM)                                                      SHEL  91
      ALFA(1)=C(4,IM)                                                   SHEL  92
      ALFA(2)=C(5,IM)                                                   SHEL  93
      ALFA(3)=C(6,IM)                                                   SHEL  94
      CM(1,1)=C(7,IM)                                                   SHEL  95
      CM(1,2)=C(8,IM)                                                   SHEL  96
      CM(1,3)=C(9,IM)                                                   SHEL  97
      CM(2,2)=C(10,IM)                                                  SHEL  98
      CM(2,3)=C(11,IM)                                                  SHEL  99
      CM(3,3)=C(12,IM)                                                  SHEL 100
      CM(2,1)=CM(1,2)                                                   SHEL 101
      CM(3,1)=CM(1,3)                                                   SHEL 102
      CM(3,2)=CM(2,3)                                                   SHEL 103
C                                                                       SHEL 104
      DO 30 I=1,5
      HM(I)=EL(I)                                                       SHEL 106
      HP(I)=EL(I)                                                       SHEL 107
      HW(I)=EL(I)                                                       SHEL 108
   30 CONTINUE
      GO TO 70                                                          SHEL 115
C                                                                       SHEL 116
   60 DO 65 I=1,NNS                                                     SHEL 117
   65 IX(I)=IX(I)+INCL                                                  SHEL 118
C                                                                       SHEL 119
   70 DO 40 I=1,NNS                                                     SHEL 120
      P(I) = 0.0
      DO 72 K=1,3
      RHO(I,K) = 0.0
      SM(I,K) = 0.0
   72 BM(I,K) = 0.0
      J=IX(I)                                                           SHEL 121
      XX(I)=X(J)                                                        SHEL 122
      YY(I)=Y(J)
   40 ZZ(I)=Z(J)                                                        SHEL 124
      IC1(NN)=IX(1)
      IC2(NN)=IX(2)
      IC3(NN)=IX(3)
      IC4(NN)=IX(4)
C                                                                       SHEL 125
C     FORM SHELL GLOBAL STIFFNESS MATRIX
C
      CALL QTSHEL (-1,NNS,NPF,MID,IDIS,IROT,ND,NTF)
C
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```
C     CLEAR STRESS CORRECTION AND LOAD VECTOR MATRICES
C
      DO 520 L=1,LL
      DO 514 I=1,NS
  514 SF(I,L) = 0.0
      DO 516 J=1,ND
  516 RF(J,L) = 0.0
  520 CONTINUE
C                                                                       SHEL 159
C     FORM ELEMENT MASS, STRESS/DISPLACEMENT AND UNIT NORMAL PRESSURE
C     FORCE MATRICES
C
      CALL STRETR(NNS,RHOM,AREAP)
C
C     FORM LOAD VECTORS AND STRESS CORRECTION MATRICES
C
      DO 550 IL=1,LL
C
C     CHECK FOR NO ELEMENT LOADINGS
      DUM = 0.0
      DO 522 K=1,5
  522 DUM = DUM + ABS(TLO(K,IL))
      IF(DUM.LT.1.0E-8) GO TO 550
C
C     GENERATE ELEMENT LOADS (MECHANICAL)
C
      DO 524 I=1,NNS
      K = 6*(I-1)
      DO 523 J=1,3
      K = K+1
      RF(K,IL) = XM(K)* TLO(J+2,IL) + PF(K)* TLO(1,IL)* EL(2)
  523 CONTINUE
      T(I)      = TLO(2,IL)* EL(3)
      DT(I)     =-TLO(2,IL)* EL(4)
  524 CONTINUE
C
C     GENERATE ELEMENT LOADS (THERMAL)
C
      DUM = ABS(T(I)) + ABS(DT(I))
      IF(DUM.LT.1.0E-8) GO TO 550
      DO 525 I=1,NNS
      DO 525 K=1,3
      SM(I,K) = 0.0
  525 BM(I,K) = 0.0
C
      CALL QTSHEL (I,NNS,NPF,MID,IDIS,IROT,ND,NTF)
C
      DO 526 I=1,ND
  526 RF(I,IL) = RF(I,IL) + R(I)
      DO 527 J=1,30
  527 R(J) = 0.0
C     ELEMENT STRESS CORRECTION MATRICES
      DO 528 I=1,NNS
      DT(I) = -DT(I)
      DO 528 K=1,3
      SM)I,K) = 0.0
  528 BM(I,K) = 0.0
C
      CALL QTSHEL (2,NNS,NPF,MID,IOIS,IROT,ND,NTF)
C
C     AVERAGE NODAL STRESSES AT THE ELEMENT CENTROID
C
      DO 530 I=1,NNS
      DO 530 K=1,3
      SF)K   ,IL) = SF(K   ,IL) + SM(I,K)
  530 SF)K+3,IL) = SF(K+3,IL) + BM(I,K)
      DUM = 1.0/ FLOAT(NNS)
      DO 532 K=1,6
  532 SF)K,IL) = SF(K,IL)* DUM
C
  550 CONTINUE
      AREAT=AREAT+AREAP*EL(I)
      WRITE(6,2004) NN,(IX)I),I=1,4),  EL(I),EL(2)
C                                                                       SHEL 151
C *** FORM LM ARRAY AND COMPUTE BANDWIDTH                               SHEL 152
C                                                                       SHEL 153
      L = MINO(NNS,4)
      DO 410 I=1,L
      J=NPF*I-NPF                                                       SHEL 155
      N=IX(I)                                                           SHEL 156
      DO 410 K=1,NPF                                                    SHEL 157
  410 LM(J+K) = 6*N +K-6
C
      DO 222 I=1,ND
      DO 222 J=1,ND
      ASA(I,J) = S)I,J)
  222 ASA(J,I) = S(I,J)
C
      CALL CALBAN (MBAND,NDIF,LM,XM,ASA,RF,ND,NDM    )
C                                                                       SHEL 169
      WRITE(10)ND,NS,(LM(I),I=1,ND),((SA(I,J),I=1,NS),J=1,ND),
     1  ((SF(I,J),I=1,NS),J=1,4),EL)I)
      GO TO 500                                                         SHEL 170
  440 WRITE (6,2005) MM                                                 SHEL 171
      ISTOP=1                                                           SHEL 172
  500 IF (NN.LT.MM) GO TO 110                                           SHEL 173
      IF (NN.EQ.NUMEL) RETURN                                           SHEL 174
      IF (ISTOP.EQ.1) STOP                                              SHEL 175
      GO TO 100                                                         SHEL 176
C                                                                       SHEL 177
 2003 FORMAT (30H1THIN PLATE/SHELL ELEMENT DATA,//
     1          8H ELEMENT,32X,11X,10H    NORMAL, /
     2          8H  NUMBER,32H  NODE-I  NODE-J  NODE-K  NODE-L,
     3         11H  THICKNESS,10H  PRESSURE, /)
 2004 FORMAT (5I8,F11.4,F10.2)
 1001 FORMAT (6I5,2F10.0)
 2005 FORMAT (19H0CARD FOR ELEMENT (,I5,14H) IS IN ERROR., / 1X)
C                                                                       SHEL 206
      END                                                               SHEL 207
      SUBROUTINE QTSHEL (KKK,NNS,NPF,MID,IDIS,IROT,NEF,NTF)            SHEL 474
C                                                                       SHEL 475
C     THIS SUBROUTINE CAN EVALUATE                                      SHEL 476
C             ... ELEMENT STIFFNESS MATRIX       ...                    SHEL 477
C             ... CONSISTENT NODAL FORCE VECTOR ...                     SHEL 478
C             ... INTERNAL STRESSES AND MOMENTS ...                     SHEL 479
C     OF A SHALLOW QUADRILATERAL SHELL ELEMENT ASSEMBLED WITH 4 FLAT    SHEL 480
C     TRIANGLES, OR OF A SINGLE TRIANGULAR SHELL ELEMENT.               SHEL 481
C                                                                       SHEL 482
C                                                                       SHEL 483
C . . . . . . . . . . . . CALLING ARGUMENTS . . . . . . . . . . . . . . SHEL 484
C                                                                       SHEL 485
C     INPUTS                                                            SHEL 486
C                                                                       SHEL 487
C      KKK        INTEGER FLAG SPECIFYING OPERATION TO BE PERFORMED     SHEL 488
C                   IF KKK =-1, FORM STIFFNESS MATRIX ONLY.             SHEL 489
C                   IF KKK = 0, FORM STIFFNESS MATRIX AND LOAD VECTOR.  SHEL 490
C                   IF KKK = 1, FORM LOAD VECTOR ONLY.                  SHEL 491
C                   IF KKK = 2, EVALUATE STRESSES AND MOMENTS.          SHEL 492
C                                                                       SHEL 493
C      NNS        NUMBER OF SUPPLIED NODAL POINTS                       SHEL 494
C                   IF NNS = 5, QTSHEL FORMS A QUADRILATERAL, AND THE   SHEL 495
C                   PROPERTIES AT THE INTERNAL NODE 5 MUST BE INPUT.    SHEL 496
C                   IF NNS = 4, QTSHEL FORMS A QUADRILATERAL, AND THE   SHEL 497
C                   PROPERTIES AT THE INTERNAL NODE 5 ARE SET BY QTSHEL SHEL 498
C                   TO BE THEIR CORNER AVERAGE.                         SHEL 499
C                   IF NNS = 3, QDSTIF FORMS A SINGLE TRIANGLE.         SHEL 500
C                                                                       SHEL 501
C      NPF        NUMBER OF GLOBAL DEGREES OF FREEDOM AT EACH           SHEL 502
C                 EXTERNAL NODE (3, 5 OR 6)                             SHEL 503
C                   IF NPF = 6, THE 3 DISPLACEMENTS U, V AND W AND THE  SHEL 504
C                   3 ROTATIONS RX, RY AND RZ ARE INCLUDED AS D.O.F.    SHEL 505
C                   IF NPF = 5, THE ROTATION RZ IS IGNORED.             SHEL 506
C                   IF NPF = 3, ONLY U, V AND W ARE CONSIDERED AND      SHEL 507
C                   THE BENDING STIFFNESS IS NOT INCLUDED (MEMBRANE     SHEL 508
C                   SHELL ELEMENT)                                      SHEL 509
C                                                                       SHEL 510
C      MID        NUMBER OF INTERNAL MIDPOINTS IN QUADRILATERAL (0 OR 4)SHEL 511
C                   IF MID = 0, THE MEMBRANE ELEMENTS ARE    CST        SHEL 512
C                           AND THE BENDING  ELEMENTS ARE    LCCT-9     SHEL 513
C                   IF MID = 4, THE MEMBRANE ELEMENTS ARE    LST-10     SHEL 514
C                           AND THE BENDING  ELEMENTS ARE    LCCT-11    SHEL 515
C                 IF NNS = 3 (SINGLE TRIANGLE) MID IS ASSUMED TO BE 0   SHEL 516
C                                                                       SHEL 517
C      IDIS       INTEGER FLAG FOR THE NODAL DISPLACEMENTS U,V,W        SHEL 518
C                   IF IDIS = 0, U,V,W ARE SPECIFIED IN THE GLOBAL SYSTEMSHEL 519
C                   IF IDIS = 1, U,V,W ARE SPECIFIED IN THE NODAL DISPL SHEL 520
C                   SYSTEMS DEFINED BY THE DIRECTION COSINE ARRAY TDIS. SHEL 521
C                                                                       SHEL 522
C      IROT       INTEGER FLAG FOR THE NODAL ROTATIONS RX,RY,RZ.        SHEL 523
C                   IF IROT = 0, RX,RY,RZ ARE SPECIFIED IN GLOBAL SYSTEM SHEL 524
C                   IF IROT = 1, RX,RY,RZ ARE SPECIFIED IN THE NODAL ROT SHEL 525
C                   SYSTEMS DEFINED BY THE DIRECTION COSINE ARRAY TROT. SHEL 526
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C                                                                         SHEL 527
C       OUTPUTS                                                           SHEL 528
C                                                                         SHEL 529
C         NEF          NUMBER OF EXTERNAL DEGREES OF FREEDOM (NEF = NPF*NEN, SHEL 530
C                      WHERE NEN=4 FOR QUADRILATERAL, =3 FOR SINGLE TRIANGLE)SHEL 531
C                                                                         SHEL 532
C         NTF          TOTAL NUMBER OF DEGREES OF FREEDOM (EXTERNAL+INTERNAL)SHEL 533
C                                                                         SHEL 534
C                                                                         SHEL 535
C * * * * * * * * * * * ARRAYS IN  COMMON /QTSARG/  * * * * * * * * * * * SHEL 536
C                                                                         SHEL 537
C X(I),Y(I),Z(I)       I=1...NN5   GLOBAL NODAL COORDINATES               SHEL 538
C                                                                         SHEL 539
C      CM(I,J)         I=1...3, J=1...3   PLANE STRESS MATERIAL MATRIX    SHEL 540
C                      RELATING STRESSES TO STRAINS IN THE LOCAL SYSTEM   SHEL 541
C                                                                         SHEL 542
C      ALFA(I)         I=1...3   DILATATION COEFFICIENTS RELATING IN-PLANE SHEL 543
C                      THERMAL STRAINS IN THE LOCAL SYSTEM TO TEMPERATURES SHEL 544
C                                                                         SHEL 545
C       HM(I)          I=1...NNS   THICKNESS RESISTING MEMBRANE STRESSES  SHEL 546
C                                                                         SHEL 547
C       HP(I)          I=1...NN5   THICKNESS RESISTING BENDING MOMENTS    SHEL 548
C                                                                         SHEL 549
C      RHO(I,J)        I=1...NN5, J=1...3  GLOBAL COMPONENTS RHOX (J=1),  SHEL 550
C                      RHOY (J=2) AND RHOZ (J=3) OF BODY FORCES PER UNIT  SHEL 551
C                      OF VOLUME                                          SHEL 552
C                                                                         SHEL 553
C       HW(I)          I=1...NN5   THICKNESS FOR COMPUTING BODY FORCES    SHEL 554
C                      RHO*HW PER UNIT OF ELEMENT AREA                    SHEL 555
C                                                                         SHEL 556
C       P(I)           I=1...NN5   LATERAL PRESSURE (NORMAL TO THE FACES OF SHEL 557
C                      THE COMPONENT TRIANGLES)                           SHEL 558
C                                                                         SHEL 559
C       T(I)           I=1...NN5   MEAN TEMPERATURE VARIATIONS            SHEL 560
C                                                                         SHEL 561
C       DT(I)          I=1...NN5   MEAN TEMPERATURE THICKNESS GRADIENTS   SHEL 562
C                                                                         SHEL 563
C      SM(I,J)         I=1...NN5, J=1...3   ARRAY OF MEMBRANE STRESS      SHEL 564
C                      COMPONENTS IN THE LOCAL SYSTEM  SIG-XX (J=1), SIG-YY SHEL 565
C                      (J=2) AND SIG-XY (J=3). SM CONTAINS                SHEL 566
C                       MEMBRANE STRESSES IN THE INITIAL POSITION AS INPUT SHEL 567
C                       WHEN KKK=0,1,2 (EXCLUDING THERMAL ACTIONS)        SHEL 568
C                       MEMBRANE STRESSES IN THE DEFORMED POSITION AS OUTPUT SHEL 569
C                       WHEN KKK=2 (INCLUDING THERMAL ACTIONS)            SHEL 570
C                                                                         SHEL 571
C      BM(I,J)         I=1...NNS, J=1...3   ARRAY OF BENDING MOMENT       SHEL 572
C                      COMPONENTS IN THE LOCAL SYSTEM  MOM-XX (J=1), MOM-YY SHEL 573
C                      (J=2) AND MOM-XY (J=3). BM CONTAINS                SHEL 574
C                       BENDING MOMENTS IN THE INITIAL POSITION AS INPUTS SHEL 575
C                       WHEN KKK=0,1,2 (EXCLUDING THERMAL ACTIONS)        SHEL 576
C                       BENDING MOMENTS IN THE DEFORMED POSITION AS OUTPUT SHEL 577
C                       WHEN KKK=2 (INCLUDING THERMAL ACTION)             SHEL 578
C                                                                         SHEL 579
C     TDIS(I,J,K)     I=1...3, J=1...3, K=1...NEN    NOT REQUIRED IF      SHEL 580
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C                         IDIS=0. IF IDIS=1, TDIS(1..3,1..3,K) MUST CONTAIN     SHEL 581
C                         THE (3,3) DIRECTION COSINE MATRIX OF THE NODAL        SHEL 582
C                         DISPLACEMENT SYSTEM AT THE K-TH ELEMENT NODE WITH     SHEL 583
C                         RESPECT TO THE GLOBAL SYSTEM                          SHEL 584
C                                                                               SHEL 585
C     TROT(I,J,K)         I=1...3, J=1...3, K=1...NEN    NOT REQUIREO IF        SHEL 586
C                         IROT=0. IF IROT=1, TROT(1..3,1..3,K) MUST CONTAIN     SHEL 587
C                         THE (3,3) DIRECTION COSINE MATRIX OF THE NODAL        SHEL 588
C                         ROTATION SYSTEM AT THE K-TH ELEMENT NOOE WITH         SHEL 589
C                         RESPECT TO THE GLOBAL SYSTEM                          SHEL 590
C                                                                               SHEL 591
C       S(I,J)            I=1...NEF, J=1...NEF  EXTERNAL STIFFNESS MATRIX       SHEL 592
C                         (OUTPUT IF KKK=-1,0)                                  SHEL 593
C                                                                               SHEL 594
C       S(I,J)            I=1...NTF, J=NEF+1...NTF   REDUCED INTERNAL STIFFNESS SHEL 595
C                         OF QUADRILATERAL ELEMENT. OUTPUT IF KKK=-1,0.         SHEL 596
C                         REQUIRED INPUT IF KKK=1,2. NOT USEO FOR SINGLE        SHEL 597
C                         TRIANGLE.                                             SHEL 598
C                                                                               SHEL 599
C        R(I)             I=1...NEF     OUTPUT EXTERNAL NODAL FORCES IF KKK=0,1. SHEL 600
C                         INPUT EXTERNAL NOOAL OISPLACEMENTS IF KKK=2.          SHEL 601
C                                                                               SHEL 602
C        R(I)             I=NEF+1...NTF   REDUCED INTERNAL NODAL FORCE VECTOR   SHEL 603
C                         OF QUADRILATERAL ELEMENT. OUTPUT IF KKK=0,1.          SHEL 604
C                         REQUIRED INPUT IF KKK=2 (RETURNS INTERNAL NOOAL       SHEL 605
C                         DISPLACEMENTS). NOT USED FOR SINGLE TRIANGLE.         SHEL 606
C                                                                               SHEL 607
C                                                                               SHEL 608
C • • • • • • • • • • ROLE OF ARRAYS IN COMMON /QTSARG/ • • • • • • • • SHEL 609
C                                                                               SHEL 610
C        ARRAYS       OPERATION  KKK =-1    KKK = 0    KKK = 1     KKK = 2      SHEL 611
C                                 Q    T     Q    T     Q    T      Q    T      SHEL 612
C                                                                               SHEL 613
C  X,Y,Z,CM,ALFA,HM,HP (*)        1    1     1    1     1    1      1    1      SHEL 614
C     RHO,HW,P                    -    -     1    1     1    1      -    -      SHEL 615
C       T,OT   (*)                -    -     1    1     1    1      1    1      SHEL 616
C       SM,BM  (*)                -    -     1    1     1    1     1/0  1/0     SHEL 617
C     TDIS,TROT (**)              1    1     1    1     1    1      1    1      SHEL 618
C  S(1..NEF,1..NEF)               0    0     0    0     -    -      -    -      SHEL 619
C S(1..NTF,NEF+1..NTF)            0    -     0    -     1    -      1    -      SHEL 620
C       R(1..NEF)                 -    -     0    0     0    0      1    1      SHEL 621
C    R(NEF+1..NTF)                -    -     0    -     0    -     1/0   -      SHEL 622
C                                                                               SHEL 623
C         WHERE    Q=QUAORILATERAL (NNS=4,5), T=SINGLE TRIANGLE (NNS=3)         SHEL 624
C                  I=INPUT, O=OUTPUT, I/O=INPUT/OUTPUT, -=NOT USED.             SHEL 625
C                                                                               SHEL 626
C    NOTES    (*)  HP,DT AND BM ARE NOT USEO IF NPF=3.                          SHEL 627
C             (**) TDIS IS NOT USEO IF IDIS=0, ANO TROT IS NOT USED             SHEL 628
C                  IF IROT=0.                                                   SHEL 629
C                                                                               SHEL 630
C                                                                               SHEL 631
      LOGICAL QUAD, TRIG, NOMP, NOST, SIST, NOLD, SILO, NOSM, SISM, SKMPSHEL 645
      COMMON /QTSARG/ X(5),Y(5),Z(5), HM(5),HP(5), CM(3,3),ALFA(3),     SHEL 632
     1 HW(5),RHO(5,3),P(5), T(5),DT(5), SM(5,3),BM(5,3), TDIS(3,3,4),   SHEL 633
     2 TROT(3,3,4),S(30,30),R(30)
      COMMON /TRIARG/ A(3),B(3), HMT(3),HPT(3), C(3,3), SMT(3,3),       SHEL 635
     1 BMT(3,3), FT(12),     P1(3),P2(3),P3(3),RM(3), ST(12,12)         SHEL 636
      COMMON /TRANSF/  T1(3),T2(3),T3(3), TO(3,3)                       SHEL 637
      DIMENSION F(1), IPERMQ(4), MFR(5), LOC(5), NC(3), CA(3), WGT(3),  SHEL 638
     1 TD1(13),TD2(13),TD3(9), TR1(9),TR2(9),TR3(9), U(1),V(1),W(1),    SHEL 639
     2 RX(1),RY(1)                                                      SHEL 640
      DIMENSION TTROT(36),TTDIS(36)
      EQUIVALENCE (TROT(1,1,1),TTROT(1)),(TDIS(1,1,1),TTDIS(1))
      EQUIVALENCE (T11,T1),(T12,T1(2)),(T13,T1(3)),(T21,T2),(T22,T2(2)),SHEL 641
     1 (T23,T2(3)),(T31,T3),(T32,T3(2)),(T33,T3(3)), (R,F),             SHEL 642
     2  (U,FT), (V,FT(7)), (W,P1), (RX,P2), (RY,P3)                     SHEL 643
      DATA  IPERMQ /2,3,4,1/, MFR /3,3,3,2,2/, WGT /.50,.50,.25/        SHEL 644
C                                                                       SHEL 646
C     INITIALIZE                                                        SHEL 647
C                                                                       SHEL 648
      SIST = KKK.LE.0                                                   SHEL 649
      NOST = .NOT.SIST                                                  SHEL 650
      SILD = KKK.EQ.0.OR.KKK.EQ.1                                       SHEL 651
      NOLD = .NOT.SILD                                                  SHEL 652
      SISM = KKK.GE.2                                                   SHEL 653
      NOSM = .NOT.SISM                                                  SHEL 654
      IF ((NNS.NE.3).AND.(NNS.NE.5))  NNS = 4                           SHEL 655
      IF ((NPF.NE.3).AND.(NPF.NE.6))  NPF = 5                           SHEL 656
      NEN = MIN0 (NNS,4)                                                SHEL 657
      QUAD = NEN.EQ.4                                                   SHEL 658
      TRIG = NEN.EQ.3                                                   SHEL 659
      WG = 1.                                                           SHEL 660
      N3 = 2*NEN - 3                                                    SHEL 661
      NTRI = 3*NEN - 8                                                  SHEL 662
      NEF = NEN*NPF                                                     SHEL 663
      NSF = NEF + (NEN-3)*NPF                                           SHEL 664
      IF (MID.NE.4)  MID = 0                                            SHEL 665
      MIDP = MID                                                        SHEL 666
      IF (TRIG)  MIDP = 0                                               SHEL 667
      NFM = 3                                                           SHEL 668
      IF (NPF.EQ.3)  NFM = 2                                            SHEL 669
      NTF = NSF + NFM*MIDP                                              SHEL 670
      NOMP = MIDP.LE.0                                                  SHEL 671
      SKMP = NOMP.OR.NOST                                               SHEL 672
      IF (NNS.NE.4)  GO TO 130                                          SHEL 673
      X(5) = 0.25*(X(1)+X(2)+X(3)+X(4))                                 SHEL 674
      Y(5) = 0.25*(Y(1)+Y(2)+Y(3)+Y(4))                                 SHEL 675
      Z(5) = 0.25*(Z(1)+Z(2)+Z(3)+Z(4))                                 SHEL 676
      HM(5) = 0.25*(HM(1)+HM(2)+HM(3)+HM(4))                            SHEL 677
      HP(5) = 0.25*(HP(1)+HP(2)+HP(3)+HP(4))                            SHEL 678
      IF (KKK.LT.0)  GO TO 130                                          SHEL 679
      T(5) = 0.25*(T(1)+T(2)+T(3)+T(4))                                 SHEL 680
      DT(5) = 0.25*(DT(1)+DT(2)+DT(3)+DT(4))                            SHEL 681
      DO 110  J = 1,3                                                   SHEL 682
      SM(5,J) = 0.25*(SM(1,J)+SM(2,J)+SM(3,J)+SM(4,J))                  SHEL 683
  110 BM(5,J) = 0.25*(BM(1,J)+BM(2,J)+BM(3,J)+BM(4,J))                  SHEL 684
      IF (NOLD)  GO TO 130                                              SHEL 685
      P(5) = 0.25*(P(1)+P(2)+P(3)+P(4))                                 SHEL 686
      HW(5) = 0.25*(HW(1)+HW(2)+HW(3)+HW(4))                            SHEL 687
      DO 120  J = 1,3                                                   SHEL 688
  120 RHO(5,J) = 0.25*(RHO(1,J)+RHO(2,J)+RHO(3,J)+RHO(4,J))             SHEL 689
  130 IF (NOST)  GO TO 150                                              SHEL 690
      DO 140  I = 1,NTF                                                 SHEL 691
      DO 140  J = 1,NTF                                                 SHEL 692
  140 S(I,J) =  0.                                                      SHEL 693
  150 IF (SISM)  GO TO 170                                              SHEL 694
      DO 160  I = 1,NTF                                                 SHEL 695
  160 F(I) = 0.                                                         SHEL 696
  170 IF (NOSM.OR.TRIG)  GO TO 200                                      SHEL 697
      NEF1 = NEF + 1                                                    SHEL 698
      DO 180  L = NEF1,NTF                                              SHEL 699
      M = L - 1                                                         SHEL 700
      DO 180  I = 1,M                                                   SHEL 701
  180 R(L) = R(L) - S(I,L)*R(I)                                         SHEL 702
  200 DO 210  I = 1,63                                                  SHEL 703
  210 A(I) = 0.                                                         SHEL 704
      DO 220  I = 1,3                                                   SHEL 705
      CA(I) = CM(1,I)*ALFA(1)+CM(2,I)*ALFA(2)+CM(3,I)*ALFA(3)           SHEL 706
      DO 220  J = 1,3                                                   SHEL 707
  220 C(I,J) = CM(I,J)                                                  SHEL 708
C                                                                       SHEL 709
C     COMPUTE DIRECTION COSINE MATRIX TO OF LOCAL ELEMENT SYSTEM        SHEL 710
C                                                                       SHEL 711
      CALL QDCOS (NTRI,X,Y,Z,TO)                                        SHEL 712
C                                                                       SHEL 713
C     LOOP OVER THE NTRI TRIANGLE COMPONENTS                            SHEL 714
C                                                                       SHEL 715
      DO 700  NT = 1,NTRI                                               SHEL 716
      N1 = NT                                                           SHEL 717
      N2 = IPERMQ(N1)                                                   SHEL 718
      NC(1) = N1                                                        SHEL 719
      NC(2) = N2                                                        SHEL 720
      NC(3) = N3                                                        SHEL 721
      MT = MIDP/2                                                       SHEL 722
      NOD = 3 + MT                                                      SHEL 723
C                                                                       SHEL 724
C     COMPUTE DIRECTION COSINES OF LOCAL TRIANGLE SYSTEM                SHEL 725
C     AND THE TRIANGLE PROJECTIONS A,B ONTO IT                          SHEL 726
C                                                                       SHEL 727
      CALL TOCOS (N1,N2,N3,X,Y,Z,A,B)                                   SHEL 728
C                                                                       SHEL 729
C     SET UP INPUTS FOR TRIANGLE SUBROUTINES                            SHEL 730
C                                                                       SHEL 731
      DO 240  I = 1,3                                                   SHEL 732
      L = NC(I)                                                         SHEL 733
      LOC(I) = NPF*(L-1)                                                SHEL 734
      HMT(I) = HM(L)                                                    SHEL 735
      HPT(I) = HP(L)                                                    SHEL 736
      IF (NOLD)  GO TO 240                                              SHEL 737
      ROX = RHO(L,1)                                                    SHEL 738
      ROY = RHO(L,2)                                                    SHEL 739
      ROZ = RHO(L,3)                                                    SHEL 740
      RO1 = T11*ROX+T12*ROY+T13*ROZ                                     SHEL 741
      RO2 = T21*ROX+T22*ROY+T23*ROZ                                     SHEL 742
      RO3 = T31*ROX+T32*ROY+T33*ROZ                                     SHEL 743
      H1 = HW(L)                                                        SHEL 744
      P1(I) = RO1*H1                                                    SHEL 745
      P2(I) = RO2*H1                                                    SHEL 746
      P3(I) = RO3*H1 + P(L)                                             SHEL 747
      TEMP = T(L)                                                       SHEL 748
      TMOM = DT(L)*HP(L)**3/12.                                         SHEL 749
      DO 230  J = 1,3                                                   SHEL 750
      SMT(I,J) = SM(L,J) - CA(J)*TEMP                                   SHEL 751
  230 BMT(I,J) = BM(L,J) - CA(J)*TMOM                                   SHEL 752
  240 CONTINUE                                                          SHEL 753
C                                                                       SHEL 754
C     FORM TRANSFORMATIONS BETWEEN ELEMENT AND NODAL SYSTEMS            SHEL 755
C                                                                       SHEL 756
      L1 = 9*N1 - 8                                                     SHEL 757
      L2 = 9*N2 - 8                                                     SHEL 758
      CALL TRFPRD(IDIS,NEN,TTDIS(L1),TTDIS(L2),TTDIS(19),TD1,TD2,TD3)
      IF (NPF.NE.3)                                                     SHEL 760
     1CALL TRFPRD(IROT,NEN,TTROT(L1),TTROT(L2),TTROT(19),TR1,TR2,TR3)
      DO 250  I = 7,8                                                   SHEL 762
      TD1(I+3) = TD1(I)                                                 SHEL 763
      TD1(I+5) = TD1(I)                                                 SHEL 764
      TD2(I+3) = TD2(I)                                                 SHEL 765
  250 TD2(I+5) = TD2(I)                                                 SHEL 766
      LOC(4) = NSF + NFM*(N2-1)                                         SHEL 767
      LOC(5) = NSF + NFM*(N1-1)                                         SHEL 768
      N4 = LOC(4) + 3                                                   SHEL 769
      N5 = LOC(5) + 3                                                   SHEL 770
C                                                                       SHEL 771
C     MEMBRANE CONTRIBUTION                                             SHEL 772
C                                                                       SHEL 773
  260 IF (SISM)  GO TO 320                                              SHEL 774
C     MEMBRANE STIFFNESS AND/OR LOAD VECTOR                             SHEL 775
      CALL SLST (MT,KKK)                                                SHEL 776
      LT = 0                                                            SHEL 777
      DO 300  JJ = 1,NOD                                                SHEL 778
      J = JJ + JJ                                                       SHEL 779
      M = LOC(JJ)                                                       SHEL 780
      LL = MFR(JJ)                                                      SHEL 781
      DO 300  L = 1,LL                                                  SHEL 782
      M = M + 1                                                         SHEL 783
      LT = LT + 1                                                       SHEL 784
      C1 = TD1(LT)                                                      SHEL 785
      C2 = TD2(LT)                                                      SHEL 786
      IF (SILD)  F(M) = F(M) + FT(J-1)*C1 + FT(J)*C2                    SHEL 787
      IF (NOST)  GO TO 300                                              SHEL 788
      KT = 0                                                            SHEL 789
      DO 290  II = 1,JJ                                                 SHEL 790
      I = II + II                                                       SHEL 791
      KK = MFR(II)                                                      SHEL 792
      IF (II.EQ.JJ)  KK = L                                             SHEL 793
      H1 = ST(I-1,J-1)*C1 + ST(I-1,J)*C2                                SHEL 794
      H2 = ST(I  ,J-1)*C1 + ST(I  ,J)*C2                                SHEL 795
      N = LOC(II)                                                       SHEL 796
      DO 290  K = 1,KK                                                  SHEL 797
      N = N + 1                                                         SHEL 798
      KT = KT + 1                                                       SHEL 799
      SQ = S(N,M) + TD1(KT)*H1 + TD2(KT)*H2                             SHEL 800
      S(N,M) = SQ                                                       SHEL 801
  290 S(M,N) = SQ                                                       SHEL 802
  300 CONTINUE                                                          SHEL 803
      GO TO 400
C     MEMBRANE STRESSES
  320 DO 350 N=1,NOD
      L = LOC(N)
      UE = R(L+1)
      VE = R(L+2)
      IF(N.GT.3) GO TO 330
      WE = R(L+3)
      M3 = 3*N
      M2 = M3-1
      M1 = M2-1
      U(N) = TD1(M1)*UE + TD1(M2)*VE + TD1(M3)*WE
      V(N) = TD2(M1)*UE + TD2(M2)*VE + TD2(M3)*WE
      W(N) = TD3(M1)*UE + TD3(M2)*VE + TD3(M3)*WE
      GO TO 350
  330 U(N) = TD1(7)*UE + TD1(8)*VE
      V(N) = TD2(7)*UE + TD2(8)*VE
  350 CONTINUE
      CALL LSTSTR (MT)
      DO 380 I=1,3
      L = NC(I)
      IF(QUAD) WG = WGT(I)
      TEMP = T(L)
      DO 380 J=1,3
  380 SM(L,J) = SM(L,J) + WG*(SMT(I,J)-CA(J)*TEMP)
  400 IF (NPF.EQ.3)  GO TO 560                                          SHEL 805
C                                                                       SHEL 806
C     PLATE BENDING CONTRIBUTION                                        SHEL 807
C                                                                       SHEL 808
      IF (SISM)  GO TO 600                                              SHEL 809
C     BENDING STIFFNESS AND/OR LOAD VECTOR                              SHEL 810
      CALL SLCCT (MT,KKK)                                               SHEL 811
      DO 500  JJ = 1,3                                                  SHEL 812
      JT = 3*JJ-3                                                       SHEL 813
      J = JT + 1                                                        SHEL 814
      DO 450  L = 1,NPF                                                 SHEL 815
      M = LOC(JJ) + L                                                   SHEL 816
      L3 = L - 3                                                        SHEL 817
      IF (L3.GT.0)  GO TO 420                                           SHEL 818
      C3 = TD3(JT+L)                                                    SHEL 819
      IF (SILD)  F(M) = F(M) + FT(J)*C3                                 SHEL 820
      IF (SKMP)  GO TO 450                                              SHEL 821
      S4 = S(M,N4) + ST(J,10)*C3                                        SHEL 822
      S5 = S(M,N5) - ST(J,11)*C3                                        SHEL 823
      GO TO 430                                                         SHEL 824
  420 C1 = TR1(JT+L3)                                                   SHEL 825
      C2 = TR2(JT+L3)                                                   SHEL 826
      IF (SILD)  F(M) = F(M) + FT(J+1)*C1 + FT(J+2)*C2                  SHEL 827
      IF (SKMP)  GO TO 450                                              SHEL 828
      S4 = S(M,N4) + ST(J+1,10)*C1 + ST(J+2,10)*C2                      SHEL 829
      S5 = S(M,N5) - ST(J+1,11)*C1 - ST(J+2,11)*C2                      SHEL 830
  430 S(M,N4) = S4                                                      SHEL 831
      S(N4,M) = S4                                                      SHEL 832
      S(M,N5) = S5                                                      SHEL 833
      S(N5,M) = S5                                                      SHEL 834
  450 CONTINUE                                                          SHEL 835
      IF (NOST)  GO TO 500                                              SHEL 836
      DO 480  II = 1,JJ                                                 SHEL 837
      IT = 3*II-3                                                       SHEL 838
      I = IT + 1                                                        SHEL 839
      KK = NPF                                                          SHEL 840
      DO 480  L = 1,NPF                                                 SHEL 841
      IF (II.EQ.JJ)  KK = L                                             SHEL 842
      M = LOC(JJ) + L                                                   SHEL 843
      L3 = L - 3                                                        SHEL 844
      IF (L3.GT.0)  GO TO 460                                           SHEL 845
      C3 = TD3(JT+L)                                                    SHEL 846
      H1 = ST(I  ,J)*C3                                                 SHEL 847
      H2 = ST(I+1,J)*C3                                                 SHEL 848
      H3 = ST(I+2,J)*C3                                                 SHEL 849
      GO TO 470                                                         SHEL 850
  460 C1 = TR1(JT+L3)                                                   SHEL 851
      C2 = TR2(JT+L3)                                                   SHEL 852
      H1 = ST(I  ,J+1)*C1 + ST(I  ,J+2)*C2                              SHEL 853
      H2 = ST(I+1,J+1)*C1 + ST(I+1,J+2)*C2                              SHEL 854
      H3 = ST(I+2,J+1)*C1 + ST(I+2,J+2)*C2                              SHEL 855
  470 N = LOC(II)                                                       SHEL 856
      DO 480  K = 1,KK                                                  SHEL 857
      N = N + 1                                                         SHEL 858
      K3 = K - 3                                                        SHEL 859
      K1 = IT + K                                                       SHEL 860
      K2 = IT + K3                                                      SHEL 861
      IF (K3.LE.0)  SQ = S(N,M) + TD3(K1)*H1                            SHEL 862
      IF (K3.GT.0)  SQ = S(N,M) + TR1(K2)*H2 + TR2(K2)*H3               SHEL 863
      S(N,M) = SQ                                                       SHEL 864
  480 S(M,N) = SQ                                                       SHEL 865
  500 CONTINUE                                                          SHEL 866
      IF (NOMP)  GO TO 700                                              SHEL 867
      IF (NOLD)  GO TO 540                                              SHEL 868
      F(N4) = F(N4) + FT(10)                                            SHEL 869
      F(N5) = F(N5) - FT(11)                                            SHEL 870
  540 IF (NOST)  GO TO 700                                              SHEL 871
      S(N4,N4) = S(N4,N4) + ST(10,10)                                   SHEL 872
      S(N5,N5) = S(N5,N5) + ST(11,11)                                   SHEL 873
      S(N4,N5) = S(N4,N5) - ST(10,11)                                   SHEL 874
      S(N5,N4) = S(N4,N5)                                               SHEL 875
      GO TO 700                                                         SHEL 876
  560 IF (NOLD)  GO TO 700                                              SHEL 877
      FL = (P3(1)+P3(2)+P3(3))*(A(3)*B(2)-A(2)*B(3))/12.                SHEL 878
      JT = 0                                                            SHEL 879
      DO 580  JJ = 1,2                                                  SHEL 880
      DO 580 L=1,3                                                      SHEL 881
      JT=JT+1                                                           SHEL 882
      M = LOC(JJ) + L                                                   SHEL 883
  580 F(M) = F(M) + FL*TD3(JT)                                          SHEL 884
      GO TO 700
C     BENDING MOMENTS
  600 DO 650 N=1,3
      L = LOC(N)
      M3 = 3*N
      M2 = M3-1
      M1 = M2-1
      XE = R(L+4)
      YE = R(L+5)
      ZE = 0.0
      IF(NPF.EQ.6) ZE = R(L+6)
      RX(N) = TR1(M1)*XE + TR1(M2)*YE + TR1(M3)*ZE
  650 RY(N) = TR2(M1)*XE + TR2(M2)*YE + TR2(M3)*ZE
      RM(1) = R(N4)
      RM(2) =-R(N5)
      CALL LCTMOM (MT)
      DO 680 I=1,3
      L = NC(I)
      IF(QUAD) WG = WGT(I)
      TMOM = DT(L)*HP(L)**3/12.0
      DO 680 J=1,3
  680 BM(L,J) = BM(L,J) + WG*(BMT(I,J)-CA(J)*TMOM)
  700 CONTINUE                                                          SHEL 886
      IF (SISM.OR.TRIG)  GO TO 900                                      SHEL 887
C                                                                       SHEL 888
C     CHECK FOR POSSIBLE INTERNAL STIFFNESS SINGULARITY (FLAT
C     OR NEARLY FLAT QUADRILATERAL WHEN NPF = 3 OR 6)                   SHEL 890
C
      IF ((NPF.EQ.5).OR.NOST)  GO TO 730                                SHEL 891
      DO 720  N = 3,6,3                                                 SHEL 892
      IF (NPF.NE.N)  GO TO 720                                          SHEL 893
      M = 5*N                                                           SHEL 894
      M1 = M - 1                                                        SHEL 895
      M2 = M - 2                                                        SHEL 896
      IF (S(M,M).GT.(S(M1,M1)+S(M2,M2))*1.0E-08)  GO TO 720             SHEL 897
      DO 710  I = 1,NTF                                                 SHEL 898
      S(I,M) = 0.                                                       SHEL 899
  710 S(M,I) = 0.                                                       SHEL 900
  720 CONTINUE                                                          SHEL 901
C                                                                       SHEL 902
C     CONDENSATION OF INTERNAL DEGREES OF FREEDOM                       SHEL 903
C                                                                       SHEL 904
  730 NIF = NTF - NEF                                                   SHEL 905
      DO 800  N = 1,NIF                                                 SHEL 906
      K = NTF - N                                                       SHEL 907
      L = K + 1                                                         SHEL 908
      PIVOT = S(L,L)                                                    SHEL 909
      FL = F(L)                                                         SHEL 910
      IF (PIVOT.LE.0.)  GO TO 800                                       SHEL 911
      F(L) = F(L)/PIVOT                                                 SHEL 912
      DO 780  I = 1,K                                                   SHEL 913
      G = S(I,L)                                                        SHEL 914
      IF (G)  740,780,740                                               SHEL 915
  740 IF (NOST)  GO TO 770                                              SHEL 916
      G = G/PIVOT                                                       SHEL 917
      S(I,L) = G                                                        SHEL 918
      DO 760  J = I,K                                                   SHEL 919
      SQ =  S(I,J) - G*S(L,J)                                           SHEL 920
      S(I,J) = SQ                                                       SHEL 921
  760 S(J,I) = SQ                                                       SHEL 922
  770 F(I) = F(I) - G*FL                                                SHEL 923
  780 CONTINUE                                                          SHEL 924
  800 CONTINUE                                                          SHEL 925
  900 RETURN                                                            SHEL 926
      END                                                               SHEL 927
      SUBROUTINE STRETR(NNS,RHOM,AREAP)
C
C     THIS ROUTINE FORMS THE ELEMENT*S MASS MATRIX AND THE
C     STRESS (MOMENT) - DISPLACEMENT TRANSFORMATION MATRIX
C     EVALUATED AT THE ELEMENT CENTROID
C     THE GLOBAL FORCES DUE TO A UNIT VALUE OF APPLIED NORMAL PRESSURE
C     ARE ALSO CALCULATED
C
      COMMON /QTSARG/
     1 XX(5),YY(5),ZZ(5),HM(5),HP(5),CM(3,3),ALFA(3),HW(5),RHO(5,3),
     2 P(5),T(5),DT(5),SM(5,3),BM(5,3),TDIS(36),TROT(36),S(30,30),
     3 R(30)
      COMMON /TRIARG/
     1 A(3),B(3),H(3),HPT(3),C(3,3),SMT(3,3),BMT(3,3),FT(12),
     2 PX(3),PY(3),PT(3),RM(3),ST(12,12)
      COMMON /EM/
     1 LM(24),ND,NS,STRAN(6,30),NC(3),AREA,XMM,TD1(13),TD2(13),
     2 TD3(9),TR1(9),TR2(9),TR3(9),SCST(3,6),XST(3,6),SLCT9(3,9),
     3 XLCT9(3,9),DUMMY(239),RF(24,4),XM(24),SA(12,24),SF(12,4),PF(24)
      COMMON /TRANSF/
     1 T1(3),T2(3),T3(3),TO(3,3)
C
      DIMENSION IPERMQ(4)
C
      DATA      IPERMQ/2,3,4,1/
C
      NEN = MIN0(NNS,4)
      WG = 1.0
      AREAP=0.0
      IF(NEN.EQ.4) WG = 0.25
      N3 = 2*NEN - 3
      NC(3) = N3
      NTRI = 3*NEN - 8
C
C     COMPUTE DIRECTION COSINE ARRAY FOR THE ELEMENT AXES
C
      CALL QDCOS (NTRI,XX,YY,ZZ,TO)
C
C     CLEAR THE MASS MATRIX VECTOR, STRESS TRANSFORMATION ARRAY AND THE
C     GLOBAL FORCE VECTOR DUE TO A UNIT NORMAL PRESSURE
C
      DO 10 K=1,ND
      XM(K) = 0.0
      PF(K) = 0.0
      DO 5 I=1,NS
    5 STRAN(I,K) = 0.0
   10 CONTINUE
      IF(NTRI.EQ.1) GO TO 20
      DO 15 I=25,30
      DO 15 J=1,NS
   15 STRAN(J,I) = 0.0
   20 CONTINUE
C
```

```
C     LOOP OVER  NTRI  TRIANGLE SUB-ELEMENTS ASSEMBLING STRESS/
C     DISPLACEMENT TRANSFORMATION AND MASS MATRICES
C
      DO 300 NT=1,NTRI
      N1 = NT
      N2 = IPERMQ(N1)
      NC(1) = N1
      NC(2) = N2
C
C     COMPUTE DIRECTION COSINES OF LOCAL TRIANGLE SYSTEM AND THE
C     TRIANGLE PROJECTIONS (A,B) ONTO THE LOCAL X,Y PLANE
C
      CALL TDCOS (N1,N2,N3,XX,YY,ZZ,A,B)
C
C     COMPUTE MASS COEFFICIENTS FOR THE SUB-ELEMENT (TRIANGLE) AND
C     ASSEMBLE INTO THE MASS ARRAY.  ALSO, COMPUTE NODAL FORCES
C     DUE TO UNIT VALUE OF NORMAL PRESSURE.
C
      AREA = (A(3)*B(2) - A(2)*B(3))* 0.5
      AREAP=AREAP+AREA
      XMM = (HW(N1)+HW(N2)+HW(N3))* AREA* RHOM/ 9.0
      FAC = AREA/ 3.0
C
      DO 40 I=1,2
      K = 6*(NC(I)-1)
      DO 30 L=1,3
      K = K+1
      PF(K) = PF(K) + FAC* T3(L)
   30 XM(K) = XM(K) + XMM
   40 CONTINUE
      DUM = XMM* 0.5
      DU2 = FAC* 0.5
      IF(NTRI.EQ.1) GO TO 45
      K1 = 6*(N1-1)
      K2 = 6*(N2-1)
      GO TO 50
   45 K1 = 6*(N3-1)
      K2 = K1
   50 DO 60 L=1,3
      K1 = K1+1
      K2 = K2+1
      PF(K1) = PF(K1) + DU2* T3(L)
      XM(K1) = XM(K1) + DUM
      PF(K2) = PF(K2) + DU2* T3(L)
   60 XM(K2) = XM(K2) + DUM
C
C     FORM TRANSFORMATIONS BETWEEN SUB-ELEMENT (TRIANGLE) LOCAL
C     SYSTEM AND THE GLOBAL COORDINATE SYSTEM
C
      CALL TRFPRD (0,NEN,TDIS,TDIS,TDIS,TD1,TD2,TD3)
      CALL TRFPRD (0,NEN,TROT,TROT,TROT,TR1,TR2,TR3)
C
C     MEMBRANE CONTRIBUTION
C
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```
      CALL CSTSTR (SCST,XST)
C
      K1 = 0
      DO 100 JJ=1,3
      M = 6*(NC(JJ)-1)
      DO 100 L=1,3
      M = M+1
      K1 = K1+1
      DO 80 K2=1,3
      STRAN(K2,M) = STRAN(K2,M) +(SCST(K2,JJ   )* TO1(K1)
     1                          + SCST(K2,JJ+3)* TO2(K1))* WG
   80 CONTINUE
  100 CONTINUE
C
C     BENDING CONTRIBUTION
C
      DO 110 K=1,3
      N = NC(K)
  110 HPT(K) = HP(N)
C
      CALL LCT9ST (SLCT9,3,XLCT9)
C
      DO 200 JJ=1,3
      I = 3*(JJ-1)
      M = 6*(NC(JJ)-1)
      DO 180 L=1,6
      M = M+1
      IF(L.GT.3) GO TO 120
      K1 = I+L
      DO 115 K2=1,3
  115 STRAN(K2+3,M) = STRAN(K2+3,M) +  SLCT9(K2,JJ)* TO3(K1)* WG
      GO TO 180
  120 K1 = I+L-3
      DO 130 K2=1,3
      STRAN(K2+3,M) = STRAN(K2+3,M) + (SLCT9(K2,JJ+3)* TR1(K1)
     1                               +  SLCT9(K2,JJ+6)* TR2(K1))* WG
  130 CONTINUE
  180 CONTINUE
  200 CONTINUE
C
  300 CONTINUE
C
C     PERFORM CONDENSATION ON INTERNAL DEGREES OF FREEDOM FOR
C     QUADRILATERAL ELEMENT'S STRESS/DISPLACEMENT TRANSFORMATION
C
      IF(NTRI.EQ.1) GO TO 500
C
      DO 400 N=1,6
      K = 30-N
      L = K+1
      PIV = S(L,L)
      IF(PIV.LT.1.0E-8) GO TO 400
      DO 390 K1=1,6
      DUM = STRAN(K1,L)
      STRAN(K1,L) = STRAN(K1,L)/ PIV
      DO 380 I=1,K
      STRAN(K1,I) = STRAN(K1,I) - S(I,L)* DUM
  380 CONTINUE
  390 CONTINUE
  400 CONTINUE
C
  500 DO 510 K1=1,NS
      DO 510 K2=1,ND
      SA(K1,K2) = STRAN(K1,K2)
  510 CONTINUE
C
      RETURN
      END
      SUBROUTINE CSTSTR (SCST,XST)
C
C     THIS SUBROUTINE FORMS THE STRESS/DISPLACEMENT TRANSFORMATION
C     MATRIX FOR A CONSTANT STRAIN TRIANGLE (CST)
C
C**** I N P U T S
C
C     A,B,C         AS IN SLST.
C
C**** O U T P U T S
C
C     SCST(I,J)     I=1...3,J=1...6.  MEMBRANE STRESSES  SIG(XX)/(I=1),
C                   SIG(YY)/(I=2), SIG(XY)/(I=3).  IN-PLANE NODAL
C                   DISPLACEMENTS  U(1)/(J=1), U(2)/(J=2), U(3)/(J=3),
C                   V(1)/(J=4), V(2)/(J=5), V(3)/(J=6).
C
      COMMON /TRIARG/
     1 A(3),B(3),H(3),HPT(3),C(3,3),SMT(3,3),BMT(3,3),
     2 U(6),V(6),W(3),RX(3),RY(3),RM(3),ST(12,12)
C
      DIMENSION     SCST(3,6),XST(3,6)
C
      DO 10 I=1,3
      XST(I,I+3) = 0.0
   10 XST(2,I   ) = 0.0
C
      AREA = A(3)* B(2) - A(2)* B(3)
      IF(AREA.LT.1.0E-8) STOP 100
      DUM = 1.0/AREA
C     STRAIN-DISPLACEMENT
      DO 20 K=1,3
      XST(1,K   ) = B(K)* DUM
      XST(2,K+3) = A(K)* DUM
      XST(3,K   ) = A(K)* DUM
   20 XST(3,K+3) = B(K)* DUM
C     STRESS-DISPLACEMENT
      DO 50 I=1,3
      DO 40 J=1,6
      SCST(I,J) = 0.0
      DO 30 K=1,3
   30 SCST(I,J) = SCST(I,J) + C(I,K)* XST(K,J)
   40 CONTINUE
   50 CONTINUE
C
      RETURN
      END
      SUBROUTINE LCT9ST (SLCT9,NODE,XLCT9)
C
C     THIS SUBROUTINE FORMS THE MOMENT RESULTANT/DISPLACEMENT TRANSFOR-
C     MATION MATRIX FOR A 3 NODE, LCCT-9, TRIANGULAR BENDING ELEMENT.
C
C**** I N P U T S
C
C     A,B,C,H      AS IN SLCCT.
C
C     NODE         NODE (1,2 OR 3) AT WHICH THE MOMENT/DISPLACEMENT
C                  IS FORMED
C
C**** O U T P U T S
C
C     SLCT9(I,J)   I=1...3, J=1...9.   MOMENT RESULTANTS AT TRIANGLE
C                  VERTEX (NODAL POINT) NUMBER *NODE* ...     M(XX)/
C                  (I=1), M(YY)/(I=2), M(XY)/(I=3).  TRANSVERSE PLATE
C                  DISPLACEMENTS  W(1)/(J=1), W(2)/(J=2), W(3)/(J=3),
C                  AND IN-PLANE ROTATIONS  RX(1)/(J=4), RX(2)/(J=5),
C                  RX(3)/(J=6), RY(1)/(J=7), RY(2)/(J=8), RY(3)/(J=9).
C
      COMMON /TRIARG/
     I A(3),B(3),HMT(3),H(3),C(3,3),SMT(3,3),BMT(3,3),
     I FT(12),U(3),TX(3),TY(3),RM(3),ST(12,12)
C
      DIMENSION    Q(3,6),IPERM(3),SLCT9(3,9),XLCT9(3,9)
C
      EQUIVALENCE  (Q,ST)
C
      DATA         IPERM/2,3,1/
C
      AREA = A(3)* B(2) - A(2)* B(3)
C
      DO 150 I=1,3
      J = IPERM(I)
      X = A(I)**2 + B(I)**2
      U(I) = -(A(I)* A(J) + B(I)* B(J))/ X
      X = SQRT(X)
      Y = 2.0* AREA/ X
      TX(I) =  Y* A(I)/ X
      TY(I) = -Y* B(I)/ X
      A1 = A(I)/ AREA
      A2 = A(J)/ AREA
      B1 = B(I)/ AREA
      B2 = B(J)/ AREA
      Q(1,I  ) =       B1* B1
      Q(2,I  ) =       A1* A1
      Q(3,I  ) = 2.0*  A1* B1
      Q(1,I+3) = 2.0*  B1* B2
      Q(2,I+3) = 2.0*  A1* A2
      Q(3,I+3) = 2.0* (A1* B2+ A2* B1)
  150 CONTINUE
C
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```
      I = NODE
      J = IPERM(I)
      K = IPERM(J)
      FAC = H(I)••3/ 12.0
      A2 = A(J)
      A3 = A(K)
      B2 = B(J)
      B3 = B(K)
      U2 = U(J)
      U3 = U(K)
      W2 = 1.0 - U2
      W3 = 1.0 - U3
C
      C21 = -(2.0+W2)• B2 - (2.0+U3)• B3 + TX(K) - TX(J)
      C22 =    82• W2 - B3• U3            + TX(K) + TX(J)
      C31 = -(2.0+W2)• A2 - (2.0+U3)• A3 + TY(K) - TY(J)
      C32 =    A2• W2 - A3• U3            + TY(K) + TY(J)
      C52 =    82- B3• W3                 - TX(K)
      C62 =    A2- A3• W3                 - TY(K)
      C82 =    B2• U2- B3                 - TX(J)
      C92 =    A2• U2- A3                 - TY(J)
      C51 =    4.0• B3 - C52
      C61 =    4.0• A3 - C62
      C81 =   -4.0• B2 - C82
      C91 =   -4.0• A2 - C92
C
      DO 250 L=1,3
      Q11 = Q(L,I)
      Q22 = Q(L,J)
      Q33 = Q(L,K)
      Q12 = Q(L,I+3)
      Q23 = Q(L,J+3)
      Q31 = Q(L,K+3)
      Q1  = Q22 - Q33
      Q2  = Q22 - Q23
      Q3  = Q33 - Q23
      Q4  = Q23 + Q1
      Q5  = G23 - Q1
C     CURVATURE - DISPLACEMENT RELATION
      XLCT9(L,I)   = -6.•Q11+3.•((U3-W2)•Q1+(U3+W2)•Q23)
      XLCT9(L,J)   =  6.•Q22+3.•  w3•Q4
      XLCT9(L,K)   =  6.•Q33+3.•  U2•Q5
      XLCT9(L,I+3) = (C21•Q1+C22•Q23+4.•(B2•Q31-B3•Q12))• 0.5
      XLCT9(L,J+3) = (C51•Q22+C52•Q3)                    • 0.5
      XLCT9(L,K+3) = (C81•Q33+C82•Q2)                    • 0.5
      XLCT9(L,I+6) = (C31•Q1+C32•Q23+4.•(A2•Q31-A3•Q12))• 0.5
      XLCT9(L,J+6) = (C61•Q22+C62•Q3)                    • 0.5
      XLCT9(L,K+6) = (C91•Q33+C92•Q2)                    • 0.5
  250 CONTINUE
C     MOMENT - DISPLACEMENT RELATION
      DO 300 I=1,3
      DO 290 J=1,9
      OUM = 0.0
      DO 280 K=1,3
  280 DUM = DUM + C(I,K)* XLCTY(K,J)
      SLCT9(I,J) = -FAC* DUM
  290 CONTINUE
  300 CONTINUE
C
      RETURN
      END
      SUBROUTINE QDCOS (N,X,Y,Z,T)                                      SHEL 928
C                                                                       SHEL 929
C     THIS SUBROUTINE COMPUTES THE DIRECTION COSINES OF THE LOCAL       SHEL 930
C     ELEMENT SYSTEM OF A QUADRILATERAL (N=4) OR SINGLE TRIANGLE (N=1)  SHEL 931
C                                                                       SHEL 932
      DIMENSION X(1), Y(1), Z(1), T(1)                                  SHEL 933
      X1 = X(2)+X(3)-X(N)-X(1)                                          SHEL 934
      Y1 = Y(2)+Y(3)-Y(N)-Y(1)                                          SHEL 935
      Z1 = Z(2)+Z(3)-Z(N)-Z(1)                                          SHEL 936
      X2 = X(3)+X(N)-X(1)-X(2)                                          SHEL 937
      Y2 = Y(3)+Y(N)-Y(1)-Y(2)                                          SHEL 938
      Z2 = Z(3)+Z(N)-Z(1)-Z(2)                                          SHEL 939
      S1 = X1**2+Y1**2+Z1**2                                            SHEL 940
      C  = (X1*X2+Y1*Y2+Z1*Z2)/S1                                       SHEL 941
      X2 = X2 - C*X1                                                    SHEL 942
      Y2 = Y2 - C*Y1                                                    SHEL 943
      Z2 = Z2 - C*Z1                                                    SHEL 944
      S1 = SQRT (S1)                                                    SHEL 945
      S2 = SQRT (X2**2+Y2**2+Z2**2)                                     SHEL 946
      X1 = X1/S1                                                        SHEL 947
      Y1 = Y1/S1                                                        SHEL 948
      Z1 = Z1/S1                                                        SHEL 949
      X2 = X2/S2                                                        SHEL 950
      Y2 = Y2/S2                                                        SHEL 951
      Z2 = Z2/S2                                                        SHEL 952
      T(1) = X1                                                         SHEL 953
      T(2) = X2                                                         SHEL 954
      T(3) = Y1*Z2-Y2*Z1                                                SHEL 955
      T(4) = Y1                                                         SHEL 956
      T(5) = Y2                                                         SHEL 957
      T(6) = Z1*X2-Z2*X1                                                SHEL 958
      T(7) = Z1                                                         SHEL 959
      T(8) = Z2                                                         SHEL 960
      T(9) = X1*Y2-X2*Y1                                                SHEL 961
      RETURN                                                            SHEL 962
      END                                                               SHEL 963
      SUBROUTINE TDCOS (N1,N2,N3,X,Y,Z,A,B)                             SHEL 964
C                                                                       SHEL 965
C     THIS SUBROUTINE COMPUTES THE DIRECTION COSINES OF THE LOCAL       SHEL 966
C     SYSTEM AND THE PROJECTED DIMENSIONS OF A TRIANGLE COMPONENT       SHEL 967
C                                                                       SHEL 968
      COMMON /TRANSF/  T1(3),T2(3),T3(3), T(9)                          SHEL 969
      EQUIVALENCE (T11,T1),(T12,T1(2)),(T13,T1(3)),(T21,T2),(T22,T2(2)),SHEL 970
     1 (T23,T2(3)),(T31,T3),(T32,T3(2)),(T33,T3(3))                     SHEL 971
      DIMENSION  X(1), Y(1), Z(1), A(1), B(1)                           SHEL 972
      A1 = X(N1)-X(N3)                                                  SHEL 973
      B1 = Y(N1)-Y(N3)                                                  SHEL 974
      C1 = Z(N1)-Z(N3)                                                  SHEL 975
      A2 = X(N2)-X(N3)                                                  SHEL 976
      B2 = Y(N2)-Y(N3)                                                  SHEL 977
      C2 = Z(N2)-Z(N3)                                                  SHEL 978
      T31  = B1*C2-B2*C1                                                SHEL 979
      T32  = C1*A2-C2*A1                                                SHEL 980
      T33  = A1*B2-A2*B1                                                SHEL 981
      S = SQRT (T31**2+T32**2+T33**2)                                   SHEL 982
      T31  = T31/S                                                      SHEL 983
      T32  = T32/S                                                      SHEL 984
      T33  = T33/S                                                      SHEL 985
      T11  = T33*T(5)-T32*T(8)                                          SHEL 986
      T12  = T31*T(8)-T33*T(2)                                          SHEL 987
      T13  = T32*T(2)-T31*T(5)                                          SHEL 988
      S = SQRT (T11**2+T12**2+T13**2)                                   SHEL 989
      T11  = T11/S                                                      SHEL 990
      T12  = T12/S                                                      SHEL 991
      T13  = T13/S                                                      SHEL 992
      T21  = T13*T32-T12*T33                                            SHEL 993
      T22  = T11*T33-T13*T31                                            SHEL 994
      T23  = T12*T31-T11*T32                                            SHEL 995
      A(1)  = -T11*A2-T12*B2-T13*C2                                     SHEL 996
      A(2)  =   T11*A1+T12*B1+T13*C1                                    SHEL 997
      B(1)  =   T21*A2+T22*B2+T23*C2                                    SHEL 998
      B(2)  = -T21*A1-T22*B1-T23*C1                                     SHEL 999
      A(3)  = -A(1)-A(2)                                                SHEL1000
      B(3)  = -B(1)-B(2)                                                SHEL1001
      RETURN                                                            SHEL1002
      END                                                               SHEL1003
      SUBROUTINE TRFPRD (M,NEN,Q1,Q2,Q3,P1,P2,P3)                       SHEL1004
C                                                                       SHEL1005
C     THIS SUBROUTINE GENERATES THE TRANSFORMATIONS RELATING A LOCAL    SHEL1006
C     SUBTRIANGLE SYSTEM TO THE NODAL DIS/ROT SYSTEMS AT ITS 3 CORNERS  SHEL1007
C                                                                       SHEL1008
      COMMON /TRANSF/  T1(3),T2(3),T3(3), T(9)                          SHEL1009
      DIMENSION  P1(1), P2(1), P3(1), Q1(1), Q2(1), Q3(1)               SHEL1010
      EQUIVALENCE (T11,T1),(T12,T1(2)),(T13,T1(3)),(T21,T2),(T22,T2(2)),SHEL1011
     1 (T23,T2(3)),(T31,T3),(T32,T3(2)),(T33,T3(3))                     SHEL1012
      DO 300  I = 1,3                                                   SHEL1013
      J = I + 3                                                         SHEL1014
      K = I + 6                                                         SHEL1015
      P1(I) = T1(I)                                                     SHEL1016
      P1(J) = T1(I)                                                     SHEL1017
      P2(I) = T2(I)                                                     SHEL1018
      P2(J) = T2(I)                                                     SHEL1019
      P3(I) = T3(I)                                                     SHEL1020
      P3(J) = T3(I)                                                     SHEL1021
      IF (NEN.NE.4)  GO TO 150                                          SHEL1022
      CI = T(I)                                                         SHEL1023
      CJ = T(J)                                                         SHEL1024
      CK = T(K)                                                         SHEL1025
      IF (M)  260,260,240                                               SHEL1026
  150 IF (M)  180,180,200                                               SHEL1027
  180 P1(K) = T1(I)                                                     SHEL1028
      P2(K) = T2(I)                                                     SHEL1029
      P3(K) = T3(I)                                                     SHEL1030
      GO TO 300                                                         SHEL1031
  200 CI = Q3(I)                                                        SHEL1032
      CJ = Q3(J)                                                        SHEL1033
      CK = Q3(K)                                                        SHEL1034
  240 P1(I) = T11*Q1(I) + T12*Q1(J) + T13*Q1(K)                         SHEL1035
      P1(J) = T11*Q2(I) + T12*Q2(J) + T13*Q2(K)                         SHEL1036
      P2(I) = T21*Q1(I) + T22*Q1(J) + T23*Q1(K)                         SHEL1037
      P2(J) = T21*Q2(I) + T22*Q2(J) + T23*Q2(K)                         SHEL1038
      P3(I) = T31*Q1(I) + T32*Q1(J) + T33*Q1(K)                         SHEL1039
      P3(J) = T31*Q2(I) + T32*Q2(J) + T33*Q2(K)                         SHEL1040
  260 P1(K) = T11*CI    + T12*CJ    + T13*CK                            SHEL1041
      P2(K) = T21*CI    + T22*CJ    + T23*CK                            SHEL1042
      P3(K) = T31*CI    + T32*CJ    + T33*CK                            SHEL1043
  300 CONTINUE                                                          SHEL1044
      RETURN                                                            SHEL1045
      END                                                               SHEL1046
      SUBROUTINE SLST (M,KKK)                                           SHEL1047
C                                                                       SHEL1048
C     THIS SUBROUTINE FORMS THE PLANE STRESS STIFFNESS MATRIX AND/OR    SHEL1049
C     THE CONSISTENT LOAD VECTOR OF A LINEAR STRAIN TRIANGLE (LST) WITH SHEL1050
C     6, 5 OR 4 NODAL POINTS, OR OF A CONSTANT STRAIN TRIANGLE (CST).   SHEL1051
C     LINEAR ELASTIC ANISOTROPIC MATERIAL                               SHEL1052
C                                                                       SHEL1053
C . . . . . . . . . . . . . . . . INPUTS . . . . . . . . . . . . . . . SHEL1054
C                                                                       SHEL1055
C      M         NUMBER OF MIDPOINTS INCLUDED AS NODAL POINTS (M=3,2,1  SHEL1056
C                FOR LST, M=0 FOR CST). NOTE.. MIDPOINTS 4-5-6 ARE      SHEL1057
C                LOCATED ON THE SIDES 2-3, 3-1 AND 1-2, RESPECTIVELY.   SHEL1058
C                                                                       SHEL1059
C     KKK        OPERATION FLAG                                         SHEL1060
C                  KKK LE 0 = FORM STIFFNESS MATRIX AND LOAD VECTOR.    SHEL1061
C                  KKK GT 0 = FORM LOAD VECTOR ONLY.                    SHEL1062
C                                                                       SHEL1063
C   A(I),B(I)    I=1...3    PROJECTIONS OF SIDES 2-3, 3-1 AND 1-2 ONTO  SHEL1064
C                X AND -Y, RESPECTIVELY.                                SHEL1065
C                                                                       SHEL1066
C    C(I,J)      I=1...3, J=1...3   PLANE STRESS MATERIAL MATRIX.       SHEL1067
C                                                                       SHEL1068
C     H(I)       I=1...3    CORNER THICKNESSES (LINEAR VARIATION ASSUMED). SHEL1069
C                                                                       SHEL1070
C PX(I),PY(I)    I=1...3    CORNER VALUES OF X-Y COMPONENTS OF BODY FORCES SHEL1071
C                PER UNIT OF ELEMENT AREA (LINEAR VARIATION ASSUMED).   SHEL1072
C                                                                       SHEL1073
C    SMT(I,J)    I=1...3, J=1...3   INITIAL MEMBRANE STRESS COMPONENTS  SHEL1074
C                SIG-XX (J=1), SIG-YY (J=2) AND SIG-XY (J=3 AT THE      SHEL1075
C                CORNERS I=1,2,3  (LINEAR VARIATION ASSUMED).           SHEL1076
C                                                                       SHEL1077
C                                                                       SHEL1078
C . . . . . . . . . . . . . . . . OUTPUTS . . . . . . . . . . . . . . .SHEL1079
C                                                                       SHEL1080
C    ST(I,J)     I=1..NDF, J=1..NDF  WITH NDF (NUMBER OF DOF) = 6+2*M, IS SHEL1081
C                THE ELEMENT STIFFNESS MATRIX ASSOCIATED WITH THE NODAL SHEL1082
C                DISPLACEMENT ORDERING                                  SHEL1083
C                    U(1),V(1),U(2),V(2),U(3), ..... V(3+M)             SHEL1084
C                WHERE U(4), ... V(3+M), IF M GT 0, ARE DEVIATIONS      SHEL1085
C                FROM LINEARITY AT THE MIDPOINTS 1...M.                 SHEL1086
C                                                                       SHEL1087
C     FT(I)      I=1..NDF   CONSISTENT NODAL FORCE VECTOR ASSOCIATED    SHEL1088
C                WITH THE NODAL DISPLACEMENT ORDERING DESCRIBED ABOVE.  SHEL1089
C                                                                       SHEL1090
C                                                                       SHEL1091
      LOGICAL NOS                                                       SHEL1097
      COMMON /TRIARG/ A(3),B(3), H(3),  HPT(3), C(3,3), SMT(3,3),       SHEL1092
     1 BMT(3,3), FT(12),    PX(3),PY(3),PT(3),RM(3), ST(12,12)          SHEL1093
      DIMENSION Q(3,3), QA(3), QB(3), A4(3), B4(3), IPERM(3),           SHEL1094
     1 SXX(3),SYY(3), SXY(3)                                            SHEL1095
      EQUIVALENCE (SXX,SMT),(SYY,SMT(4)),(SXY,SMT(7))                   SHEL1096
      DATA  IPERM /2,3,1/                                               SHEL1098
      NOS = KKK.GT.0                                                    SHEL1099
      NDF = 6 + 2*M                                                     SHEL1100
      AREA = A(3)*B(2)-A(2)*B(3)                                        SHEL1101
      SUMH = H(1)+H(2)+H(3)                                             SHEL1102
      HO = SUMH/3.                                                      SHEL1103
      IF (HO) 500,500,140                                               SHEL1104
  140 PXS = PX(1)+PX(2)+PX(3)                                           SHEL1105
      PYS = PY(1)+PY(2)+PY(3)                                           SHEL1106
      SXXH = 0.                                                         SHEL1107
      SYYH = 0.                                                         SHEL1108
      SXYH = 0.                                                         SHEL1109
      DO 150  I = 1,3                                                   SHEL1110
      CH = (SUMH+H(I))/24.                                              SHEL1111
      SXXH = SXXH + CH*SXX(I)                                           SHEL1112
      SYYH = SYYH + CH*SYY(I)                                           SHEL1113
  150 SXYH = SXYH + CH*SXY(I)                                           SHEL1114
      FAC = HO/(2.*AREA)                                                SHEL1115
      C11 = C(1,1)*FAC                                                  SHEL1116
      C22 = C(2,2)*FAC                                                  SHEL1117
      C33 = C(3,3)*FAC                                                  SHEL1118
      C12 = C(1,2)*FAC                                                  SHEL1119
      C13 = C(1,3)*FAC                                                  SHEL1120
      C23 = C(2,3)*FAC                                                  SHEL1121
      DO 200  J = 1,3                                                   SHEL1122
      L = J + J                                                         SHEL1123
      FT(L-1) = (PXS+PX(J))*AREA/24. - (B(J)*SXXH+A(J)*SXYH)            SHEL1124
      FT(L)   = (PYS+PY(J))*AREA/24. - (A(J)*SYYH+B(J)*SXYH)            SHEL1125
      IF (NOS)  GO TO 200                                               SHEL1126
  180 DO 190  I = 1,J                                                   SHEL1127
      K = I + I                                                         SHEL1128
      AA = A(I)*A(J)                                                    SHEL1129
      BB = B(I)*B(J)                                                    SHEL1130
      AB = A(I)*B(J)                                                    SHEL1131
      BA = B(I)*A(J)                                                    SHEL1132
      ABA = AB+BA                                                       SHEL1133
      ST(K-1,L-1) = C11*BB + C33*AA + C13*ABA                           SHEL1134
      ST(K  ,L  ) = C22*AA + C33*BB + C23*ABA                           SHEL1135
      ST(K-1,L  ) = C12*BA + C33*AB + C13*AA + C23*BB                   SHEL1136
  190 ST(K  ,L-1) = C12*AB + C33*BA + C13*BB + C23*AA                   SHEL1137
  200 CONTINUE                                                          SHEL1138
      IF (M) 350,350,220                                                SHEL1139
  220 DO 240  I = 1,3                                                   SHEL1140
      A4(I) = 4.*A(I)                                                   SHEL1141
      B4(I) = 4.*B(I)                                                   SHEL1142
      J = IPERM(I)                                                      SHEL1143
      K = IPERM(J)                                                      SHEL1144
      R = H(I)/HO                                                       SHEL1145
      Q(I,I) = 0.1+R/15.                                                SHEL1146
      Q(J,K) = 0.1-R/60.                                                SHEL1147
  240 Q(K,J) = Q(J,K)                                                   SHEL1148
      DO 300  J = 1,M                                                   SHEL1149
      J1 = IPERM(J)                                                     SHEL1150
      J2 = IPERM(J1)                                                    SHEL1151
      L = J + J + 6                                                     SHEL1152
      FX = 0.                                                           SHEL1153
      FY = 0.                                                           SHEL1154
      DO 250  N = 1,3                                                   SHEL1155
      Q1 = Q(N,J1)                                                      SHEL1156
      Q2 = Q(N,J2)                                                      SHEL1157
      QA(N) = Q2*A4(J1)+Q1*A4(J2)                                       SHEL1158
      QB(N) = Q2*B4(J1)+Q1*B4(J2)                                       SHEL1159
      FX = FX - QB(N)*SXX(N)-QA(N)*SXY(N)                               SHEL1160
  250 FY = FY - QA(N)*SYY(N)-QB(N)*SXY(N)                               SHEL1161
      FT(L-1) = (PXS-PX(J))*AREA/12. + FX*HO/2.                         SHEL1162
      FT(L)   = (PYS-PY(J))*AREA/12. + FY*HO/2.                         SHEL1163
      IF (NOS)  GO TO 300                                               SHEL1164
      SUMQA = QA(1)+QA(2)+QA(3)                                         SHEL1165
      SUMQB = QB(1)+QB(2)+QB(3)                                         SHEL1166
      JM = J + 3                                                        SHEL1167
      DO 290  I = 1,JM                                                  SHEL1168
      K = I + 1                                                         SHEL1169
      IF (I.GT.3) GO TO 260                                             SHEL1170
      AA = A(I)*SUMQA                                                   SHEL1171
      AB = A(I)*SUMQB                                                   SHEL1172
      BA = B(I)*SUMQA                                                   SHEL1173
      BB = B(I)*SUMQB                                                   SHEL1174
      GO TO 280                                                         SHEL1175
  260 I1 = IPERM(I-3)                                                   SHEL1176
      I2 = IPERM(I1)                                                    SHEL1177
      AA = A4(I2)*QA(I1)+A4(I1)*QA(I2)                                  SHEL1178
      AB = A4(I2)*QB(I1)+A4(I1)*QB(I2)                                  SHEL1179
      BA = B4(I2)*QA(I1)+B4(I1)*QA(I2)                                  SHEL1180
      BB = B4(I2)*QB(I1)+B4(I1)*QB(I2)                                  SHEL1181
  280 ABA = AB+BA                                                       SHEL1182
      ST(K-1,L-1) = C11*BB + C33*AA + C13*ABA                           SHEL1183
      ST(K  ,L  ) = C22*AA + C33*BB + C23*ABA                           SHEL1184
      ST(K-1,L  ) = C12*BA + C33*AB + C13*AA + C23*BB                   SHEL1185
  290 ST(K  ,L-1) = C12*AB + C33*BA + C13*BB + C23*AA                   SHEL1186
  300 CONTINUE                                                          SHEL1187
  350 DO 400  I = 2,NDF                                                 SHEL1188
      DO 400  J = 1,I                                                   SHEL1189
  400 ST(I,J) = ST(J,I)                                                 SHEL1190
  500 RETURN                                                            SHEL1191
      END                                                               SHEL1192
      SUBROUTINE SLCCT (M,KKK)                                          SHEL1193
C                                                                       SHEL1194
C     THIS SUBROUTINE FORMS THE PLATE BENDING STIFFNESS AND/OR THE      SHEL1195
C     CONSISTENT LOAD VECTOR OF A LINEAR CURVATURE COMPATIBLE TRIANGLE  SHEL1196
C     (LCCT) WITH 6, 5, 4 OR 3 NODAL POINTS                             SHEL1197
C                                                                       SHEL1198
C                                                                       SHEL1199
C • • • • • • • • • • • • • • • • INPUTS • • • • • • • • • • • • • • • • SHEL1200
C                                                                       SHEL1201
C       M        NUMBER OF MIDPOINT DEGREES OF FREEDOM (M =3,2,1,0).    SHEL1202
C                NOTE.. MIDPOINTS 4-5-6 (IF INCLUDED) ARE LOCATED ON    SHEL1203
C                SIDES 2-3, 3-1 AND 1-2, RESPECTIVELY.                  SHEL1204
C                                                                       SHEL1205
C      KKK       OPERATION FLAG                                         SHEL1206
C                  KKK LE 0 = FORM STIFFNESS MATRIX AND LOAD VECTOR.    SHEL1207
C                  KKK GT 0 = FORM LOAD VECTOR ONLY.                    SHEL1208
C                                                                       SHEL1209
C  A(I),B(I)     I=1...3    PROJECTIONS OF SIDES 2-3, 3-1 AND 1-2 ONTO  SHEL1210
C                X AND -Y, RESPECTIVELY.                                SHEL1211
C                                                                       SHEL1212
C   C(I,J)       I=1...3, J=1...3   PLANE STRESS MATERIAL MATRIX.       SHEL1213
C                                                                       SHEL1214
C    H(I)        I=1...3   CORNER THICKNESSES (LINEAR VARIATION ASSUMED). SHEL1215
C                                                                       SHEL1216
C    PT(I)       I=1...3   CORNER VALUES OF LATERAL DISTRIBUTED LOAD    SHEL1217
C                (LINEAR VARIATION ASSUMED).                            SHEL1218
C                                                                       SHEL1219
C   BMT(I,J)     I=1...3, J=1...3   INITIAL BENDING MOMENT COMPONENTS   SHEL1220
C                MOM-XX (J=1), MOM-YY (J=2) AND MOM-XY (J=3) AT THE     SHEL1221
C                CORNERS I=1...3  (LINEAR VARIATION ASSUMED).           SHEL1222
C                                                                       SHEL1223
C                                                                       SHEL1224
C • • • • • • • • • • • • • • • • OUTPUTS • • • • • • • • • • • • • • • • SHEL1225
C                                                                       SHEL1226
C   ST(I,J)      I=1..NDF, J=1..NDF  WITH NDF (NUMBER OF DOF) = 9+M, IS SHEL1227
C                THE ELEMENT STIFFNESS MATRIX ASSOCIATED WITH THE NODAL SHEL1228
C                DISPLACEMENT ORDERING                                  SHEL1229
C                  W(1),RX(1),RY(1),W(2), .... RY(3),RM(1), ... RM(M)   SHEL1230
C                WHERE RM(1), ... RM(M), IF M GT 0, ARE MIDPOINT        SHEL1231
C                DEVIATIONS FROM NORMAL SLOPE LINEARITY                 SHEL1232
C                                                                       SHEL1233
C    FT(I)       I=1..NDF   CONSISTENT NODAL FORCE VECTOR ASSOCIATED    SHEL1234
C                WITH THE NODAL DISPLACEMENT ORDERING DESCRIBED ABOVE.  SHEL1235
C                                                                       SHEL1236
C                                                                       SHEL1237
      LOGICAL NOS, FLAT                                                 SHEL1244
      COMMON /TRIARG/ A(3),B(3), HMT(3), H(3),  C(3,3), SMT(3,3),       SHEL1238
     1 BMT(3,3), FT(12),     PX(3),PY(3),PT(3),RM(3), ST(12,12)         SHEL1239
      DIMENSION  P(21,12), G(21), Q(3,6), QB(3,6), T(3), U(3), HT(3),   SHEL1240
     1 TX(3), TY(3), IPERM(3), XM(3,3), XMO(3)                          SHEL1241
      EQUIVALENCE (CM11,C(1)),(CM12,C(2)),(CM13,C(3)),(CM22,C(5)),      SHEL1242
     1 (CM23,C(6)),(CM33,C(9))                                          SHEL1243
      DATA IPERM/2,3,1/                                                 SHEL1245
      HO = (H(1)+H(2)+H(3))/3.                                          SHEL1246
      IF (HO.LE.0.)  GO TO 1000                                         SHEL1247
      NDF = 9 + M                                                       SHEL1248
      NOS = KKK.GT.0                                                    SHEL1249
      FLAT = (H(1).EQ.H(2)).AND.(H(2).EQ.H(3))                          SHEL1250
      AREA = A(3)*B(2)-A(2)*B(3)                                        SHEL1251
      FAC = HO**3*AREA/864.                                             SHEL1252
      PTF = AREA/6480.                                                  SHEL1253
      T(3) = 1.                                                         SHEL1254
      DO 150  I = 1,3                                                   SHEL1255
      J = IPERM(I)                                                      SHEL1256
      K = IPERM(J)                                                      SHEL1257
      X = A(I)**2+B(I)**2                                               SHEL1258
      U(I) = -(A(I)*A(J)+B(I)*B(J))/X                                   SHEL1259
      X = SQRT(X)                                                       SHEL1260
      Y = 2.*AREA/X                                                     SHEL1261
      HT(I) =  2.*Y                                                     SHEL1262
      TX(I) =  Y*A(I)/X                                                 SHEL1263
      TY(I) = -Y*B(I)/X                                                 SHEL1264
      A1 = A(I)/AREA                                                    SHEL1265
      A2 = A(J)/AREA                                                    SHEL1266
      B1 = B(I)/AREA                                                    SHEL1267
      B2 = B(J)/AREA                                                    SHEL1268
      Q(1,I)   = B1*B1                                                  SHEL1269
      Q(2,I)   = A1*A1                                                  SHEL1270
      Q(3,I)   = 2.*A1*B1                                               SHEL1271
      Q(1,I+3) = 2.*B1*B2                                               SHEL1272
      Q(2,I+3) = 2.*A1*A2                                               SHEL1273
      Q(3,I+3) = 2.*(A1*B2+A2*B1)                                       SHEL1274
      DO 120  N = 1,3                                                   SHEL1275
  120 XM(N,I) = BMT(N,I)*AREA/72.                                       SHEL1276
      IF (FLAT)  GO TO 150                                              SHEL1277
      DO 140  N = 1,3                                                   SHEL1278
      L = IPERM(N)                                                      SHEL1279
      T(1) = H(N)/HO                                                    SHEL1280
      T(2) = H(L)/HO                                                    SHEL1281
      IF (T(1).GT.0.)  XM(N,I) = XM(N,I)/T(1)**3                        SHEL1282
      C1 = T(I)                                                         SHEL1283
      C2 = T(J)                                                         SHEL1284
      C3 = T(K)                                                         SHEL1285
      C4 = C2+C3                                                        SHEL1286
      C11 = C1*C1                                                       SHEL1287
      C23 = C2*C3                                                       SHEL1288
      C5 = C4*(3.*C1+C4) + 6.*C11 - 2.*C23                              SHEL1289
      C6 = C5 + 3.*C4*C4 - 4.*(C11+C23)                                 SHEL1290
      QB(N,I  ) = (C1*(10.*C11-3.*C23)+C4*C5)/17.5 - 2.0                SHEL1291
  140 QB(N,I+3) = (C1*(C11-2.*C23)+C4*C6)/35.0 - 1.0                    SHEL1292
  150 CONTINUE                                                          SHEL1293
      DO 200  I = 1,3                                                   SHEL1294
      J = IPERM(I)                                                      SHEL1295
      K = IPERM(J)                                                      SHEL1296
      II = 3*I                                                          SHEL1297
      JJ = 3*J                                                          SHEL1298
      KK = 3*K                                                          SHEL1299
      A1 = A(I)                                                         SHEL1300
      A2 = A(J)                                                         SHEL1301
      A3 = A(K)                                                         SHEL1302
      B1 = B(I)                                                         SHEL1303
      B2 = B(J)                                                         SHEL1304
      B3 = B(K)                                                         SHEL1305
      U1 = U(I)                                                         SHEL1306
      U2 = U(J)                                                         SHEL1307
      U3 = U(K)                                                         SHEL1308
      W1 = 1.-U1                                                        SHEL1309
      W2 = 1.-U2                                                        SHEL1310
      W3 = 1.-U3                                                        SHEL1311
      B1D = B1 + B1                                                     SHEL1312
      B2D = B2 + B2                                                     SHEL1313
      B3D = B3 + B3                                                     SHEL1314
      A1D = A1 + A1                                                     SHEL1315
      A2D = A2 + A2                                                     SHEL1316
      A3D = A3 + A3                                                     SHEL1317
      C21 = B1-B3*U3          + TX(K)                                   SHEL1318
      C22 = -B1D+B2*W2+B3*U3  + TX(J)-TX(K)                             SHEL1319
      C31 = A1-A3*U3          + TY(K)                                   SHEL1320
      C22 = -B1D+B2*W2+B3*U3  + TX(J)-TX(K)                             SHEL1321
      C31 = A1-A3*U3          + TY(K)                                   SHEL1322
      C32 = -A1D+A2*W2+A3*U3  + TY(J)-TY(K)                             SHEL1323
      C51 = B3*W3-B2          + TX(K)                                   SHEL1324
      C52 = B2D-B3*W3-B1*U1   + TX(I)-TX(K)                             SHEL1325
      C61 = A3*W3-A2          + TY(K)                                   SHEL1326
      C62 = A2D-A3*W3-A1*U1   + TY(I)-TY(K)                             SHEL1327
      C81 = B3-B2D-B2*U2      + TX(J)                                   SHEL1328
      C82 = B1D-B3+B1*W1      + TX(I)                                   SHEL1329
      C91 = A3-A2D-A2*U2      + TY(J)                                   SHEL1330
      C92 = A1D-A3+A1*W1      + TY(I)                                   SHEL1331
      P1 = PT(I)*PTF                                                    SHEL1332
      P2 = PT(J)*PTF                                                    SHEL1333
      P3 = PT(K)*PTF                                                    SHEL1334
      U37 = 7.*U3                                                       SHEL1335
      W27 = 7.*W2                                                       SHEL1336
      W24 = 4.*W2                                                       SHEL1337
      U34 = 4.*U3                                                       SHEL1338
      C1 = 54.+W27                                                      SHEL1339
      C2 = 54.+U37                                                      SHEL1340
      C3 = 15.+W24                                                      SHEL1341
      C4 = 39.+U37                                                      SHEL1342
      C5 = 39.+W27                                                      SHEL1343
      C6 = 15.+U34                                                      SHEL1344
      TXS = TX(J)+TX(K)                                                 SHEL1345
      TYS = TY(J)+TY(K)                                                 SHEL1346
      FT(II-2) = 6.*((90.+U37+W27)*P1+(36.+U37+W24)*P2+(36.+U34+W27)*P3)SHEL1347
      FT(II-1) = (C1*B2-C2*B3+7.*TXS)*P1 + (C3*B2-C4*B3+4.*TXS+         SHEL1348
     1 3.*TX(K))*P2 + (C5*B2-C6*B3+4.*TXS+3.*TX(J))*P3                  SHEL1349
      FT(II)   = (C1*A2-C2*A3+7.*TYS)*P1 + (C3*A2-C4*A3+4.*TYS+         SHEL1350
     1 3.*TY(K))*P2 + (C5*A2-C6*A3+4.*TYS+3.*TY(J))*P3                  SHEL1351
      FT(K+9)  = (7.*(P1+P2)+4.*P3)*HT(K)                               SHEL1352
      XMO(I) = (XM(1,I)+XM(2,I)+XM(3,I))/3.                             SHEL1353
      DO 200  N = 1,3                                                   SHEL1354
      L = 6*(I-1) + N                                                   SHEL1355
      Q11 = Q(N,I)                                                      SHEL1356
      Q22 = Q(N,J)                                                      SHEL1357
      Q33 = Q(N,K)                                                      SHEL1358
      Q12 = Q(N,I+3)                                                    SHEL1359
      Q23 = Q(N,J+3)                                                    SHEL1360
      Q31 = Q(N,K+3)                                                    SHEL1361
      Q2333 = Q23-Q33                                                   SHEL1362
      Q3133 = Q31-Q33                                                   SHEL1363
      P(L    ,II-2) = 6.*(-Q11+W2*Q33+U3*Q2333)                         SHEL1364
      P(L    ,II-1) = C21*Q23+C22*Q33-B3D*Q12+B2D*Q31                   SHEL1365
      P(L    ,II  ) = C31*Q23+C32*Q33-A3D*Q12+A2D*Q31                   SHEL1366
      P(L    ,JJ-2) = 6.*(Q22+W3*Q2333)                                 SHEL1367
      P(L    ,JJ-1) = C51*Q2333+B3D*Q22                                 SHEL1368
      P(L    ,JJ  ) = C61*Q2333+A3D*Q22                                 SHEL1369
      P(L    ,KK-2) = 6.*(1.+U2)*Q33                                    SHEL1370
      P(L    ,KK-1) = C81*Q33                                           SHEL1371
      P(L    ,KK  ) = C91*Q33                                           SHEL1372
      P(L    ,I+9 ) = 0.                                                SHEL1373
      P(L    ,J+9 ) = HT(J)*Q33                                         SHEL1374
      P(L    ,K+9 ) = HT(K)*Q2333                                       SHEL1375
      P(L+3  ,II-2) = 6.*(Q11+U3*Q3133)                                 SHEL1376
      P(L+3  ,II-1) = C21*Q3133-B3D*Q11                                 SHEL1377
      P(L+3  ,II  ) = C31*Q3133-A3D*Q11                                 SHEL1378
      P(L+3  ,JJ-2) = 6.*(-Q22+U1*Q33+W3*Q3133)                         SHEL1379
      P(L+3  ,JJ-1) = C51*Q31+C52*Q33+B3D*Q12-B1D*Q23                   SHEL1380
      P(L+3  ,JJ  ) = C61*Q31+C62*Q33+A3D*Q12-A1D*Q23                   SHEL1381
      P(L+3  ,KK-2) = 6.*(1.+W1)*Q33                                    SHEL1382
      P(L+3  ,KK-1) = C82*Q33                                           SHEL1383
      P(L+3  ,KK  ) = C92*Q33                                           SHEL1384
      P(L+3  ,I+9 ) = HT(I)*Q33                                         SHEL1385
      P(L+3  ,J+9 ) = 0.                                                SHEL1386
      P(L+3  ,K+9 ) = HT(K)*Q3133                                       SHEL1387
      P(N+18,II-2) = 2.*(Q11+U3*Q12+W2*Q31)                             SHEL1388
      P(N+18,KK-1) = ((B1D-B2D)*Q33+C82*Q23+C81*Q31)/3.                 SHEL1389
      P(N+18,KK  ) = ((A1D-A2D)*Q33+C92*Q23+C91*Q31)/3.                 SHEL1390
  200 P(N+18,K+9 ) = HT(K)*Q12/3.                                       SHEL1391
  300 DO 400  J = 1,NDF                                                 SHEL1392
      DO 340  L = 1,3                                                   SHEL1393
      II = L                                                            SHEL1394
      KK = L + 18                                                       SHEL1395
      P3 = P(KK,J)                                                      SHEL1396
      G(KK) = 0.                                                        SHEL1397
      DO 340  N = 1,3                                                   SHEL1398
      I = IPERM(N)                                                      SHEL1399
      JJ = II + 3                                                       SHEL1400
      P1 = P(II,J)                                                      SHEL1401
      P2 = P(JJ,J)                                                      SHEL1402
      SUM = P1 + P2 + P3                                                SHEL1403
      G1 = SUM + P1                                                     SHEL1404
      G2 = SUM + P2                                                     SHEL1405
      G3 = SUM + P3                                                     SHEL1406
      IF (FLAT)  GO TO 320                                              SHEL1407
      G1 = G1 + QB(N,1)*P1 + QB(N,6)*P2 + QB(N,5)*P3                    SHEL1408
      G2 = G2 + QB(N,6)*P1 + QB(N,2)*P2 + QB(N,4)*P3                    SHEL1409
      G3 = G3 + QB(N,5)*P1 + QB(N,4)*P2 + QB(N,3)*P3                    SHEL1410
  320 G(II) = G1                                                        SHEL1411
      G(JJ) = G2                                                        SHEL1412
      G(KK) = G3 + G(KK)                                                SHEL1413
      II = II + 6                                                       SHEL1414
  340 FT(J) = FT(J) - XM(N,L)*G1 - XM(I,L)*G2 - XMO(L)*G3               SHEL1415
      IF (NOS)  GO TO 400                                               SHEL1416
      DO 360 N = 1,19,3
      G1 = G(N)                                                         SHEL1418
      G2 = G(N+1)                                                       SHEL1419
      G3 = G(N+2)                                                       SHEL1420
      G(N)   = CM11*G1 + CM12*G2 + CM13*G3                              SHEL1421
      G(N+1) = CM12*G1 + CM22*G2 + CM23*G3                              SHEL1422
  360 G(N+2) = CM13*G1 + CM23*G2 + CM33*G3                              SHEL1423
      DO 390  I = 1,J                                                   SHEL1424
      X = 0.                                                            SHEL1425
      DO 380  N = 1,21                                                  SHEL1426
  380 X = X + G(N)*P(N,I)                                               SHEL1427
      X = X*FAC                                                         SHEL1428
      ST(I,J) = X                                                       SHEL1429
  390 ST(J,I) = X                                                       SHEL1430
  400 CONTINUE                                                          SHEL1431
 1000 RETURN                                                            SHEL1432
      END                                                               SHEL1433
      SUBROUTINE LSTSTR (M)
C
C     THIS SUBROUTINE COMPUTES THE IN-PLANE STRESSES IN A LINEAR STRAIN
C     TRIANGLE (LST) WITH 6, 5 OR 4 NODAL POINTS, OR IN A CONSTANT
C     STRAIN TRIANGLE (CST)
C
C
C * * * * * * * * * * * * * * * INPUTS * * * * * * * * * * * * * * *
C
C  M,A,B,C      AS IN SLST.
C
C  U(I),V(I)    I=1...3+M    IN-PLANE NODAL DISPLACEMENT COMPONENTS.  THE
C               MIDPOINT VALUES U(I),V(I),I=4...3+M, IF ANY, ARE
C               DEVIATIONS FROM LINEARITY
C
C * * * * * * * * * * * * * * OUTPUTS * * * * * * * * * * * * * * *
C
C  SMT(I,J)     I=1...3, J=1...3    MEMBRANE STRESS COMPONENTS  SIG-XX
C               (J=1), SIG-YY (J=2), AND SIG-XY (J=3) AT THE CORNERS
C               I=1...3, ASSOCIATED WITH THE INPUT DISPLACEMENTS
C
C
      COMMON /TRIARG/ A(3),B(3),H(3),HPT(3),C(3,3),SMT(3,3),
     1 BMT(3,3),U(6),V(6),W(3),RX(3),RY(3),RM(3),ST(12,12)
      DIMENSION  EXX(3),EYY(3),GXY(3),EPS(3,3),IPERM(3)
      EQUIVALENCE (EXX,EPS), (EYY,EPS(4)), (GXY,EPS(7))
      DATA  IPERM /2,3,1/
      AREA = A(3)*B(2)-A(2)*B(3)
      E11 =  (B(1)*U(1)+B(2)*U(2)+B(3)*U(3))/AREA
      E22 =  (A(1)*V(1)+A(2)*V(2)+A(3)*V(3))/AREA
      G12 =  (A(1)*U(1)+A(2)*U(2)+A(3)*U(3)+B(1)*V(1)+B(2)*V(2)
     1       +B(3)*V(3))/AREA
      DO 150 I=1,3
      EXX(I) = E11
      EYY(I) = E22
  150 GXY(I) = G12
      IF(M.LE.0) GO TO 250
      DO 200 I=1,M
      X = 4.0*U(I+3)/AREA
      Y = 4.0*V(I+3)/AREA
      J = IPERM(I)
      K = IPERM(J)
      EXX(J) = EXX(J) + B(K)*X
      EXX(K) = EXX(K) + B(J)*X
      EYY(J) = EYY(J) + A(K)*Y
      EYY(K) = EYY(K) + A(J)*Y
      GXY(J) = GXY(J) + A(K)*X + B(K)*Y
  200 GXY(K) = GXY(K) + A(J)*X + B(J)*Y
  250 DO 300 I=1,3
      DO 300 J=1,3
  300 SMT(I,J) = C(J,1)*EPS(I,1)+C(J,2)*EPS(I,2)+C(J,3)*EPS(I,3)
      RETURN
      END
      SUBROUTINE LCTMOM (M)
C
C     THIS SUBROUTINE COMPUTES THE BENDING MOMENT FIELD IN A LCCT
C     PLATE BENDING ELEMENT WITH 6, 5, 4 OR 3 NODAL POINTS
C
C
C * * * * * * * * * * * * * * * *   INPUTS   * * * * * * * * * * * * * * * *
C
C  M,A,B,C,H  AS IN SLCCT.
C   W(I)        I=1...3   CORNER Z-DISPLACEMENTS
C RX(I)/RY(I) I=1...3   CORNER X/Y ROTATIONS
C   RM(I)       I=1...3   IF(M.GT.0), MIDPOINT SIDE ROTATIONS (DEVIATIONS
C               FROM NORMAL SLOPE LINEARITY)
C
C * * * * * * * * * * * * * * *   OUTPUTS   * * * * * * * * * * * * * * * * *
C
C   BMT(I,J)  I=1...3, J=1...3   BENDING MOMENT COMPONENTS  MOM-XX
C             (J=1), MOM-YY (J=2), AND MOM-XY (J=3) AT THE CORNERS
C             I=1...3  ASSOCIATED WITH THE INPUT DISPLACEMENTS
C
C
      COMMON /TRIARG/ A(3),B(3),HMT(3),H(3),C(3,3),SMT(3,3),
     1 BMT(3,3),FT(12),W(3),RX(3),RY(3),RM(3),ST(12,12)
      DIMENSION U(3),Q(3,6),CV(3),IPERM(3),TX(3),TY(3),RH(3)
      EQUIVALENCE (Q,ST)
      DATA  IPERM /2,3,1/
      AREA = A(3)*B(2)-A(2)*B(3)
      DO 150 I=1,3
      J = IPERM(I)
      X = A(I)**2+B(I)**2
      U(I) = -(A(I)*A(J)+B(I)*B(J))/X
      X = SQRT(X)
      Y = 2.*AREA/X
      RH(I) = 0.0
      IF(I.LE.M) RH(I) = 2.*Y*RM(I)
      TX(I) =  Y*A(I)/X
      TY(I) = -Y*B(I)/X
      A1 = A(I)/AREA
      A2 = A(J)/AREA
      B1 = B(I)/AREA
      B2 = B(J)/AREA
      Q(1,I) = B1*B1
      Q(2,I) = A1*A1
      Q(3,I) = 2.* A1*B1
      Q(1,I+3) = 2.* B1*B2
      Q(2,I+3) = 2.* A1*A2
  150 Q(3,I+3) = 2.*(A1*B2+A2*B1)
      DO 300 I=1,3
      J = IPERM(I)
      K = IPERM(J)
      FAC = H(I)**3/ 12.0
      A2 = A(J)
      A3 = A(K)
      B2  =  B(J)
      B3  =  B(K)
      U2  =  U(J)
      U3  =  U(K)
      W2  =  1.0  -  U2
      W3  =  1.0  -  U3
      C21  =  -(2.0+W2)*  B2  -  (2.0+U3)*  B3  +  TX(K)  -  TX(J)
      C22  =     B2*  W2  -  B3*  U3            +  TX(K)  +  TX(J)
      C31  =  -(2.0+W2)*  A2  -  (2.0+U3)*  A3  +  TY(K)  -  TY(J)
      C32  =     A2*  W2  -  A3*  U3            +  TY(K)  +  TY(J)
      C52  =     B2-  B3*  W3                   -  TX(K)
      C62  =     A2-  A3*  W3                   -  TY(K)
      C82  =     B2*  U2-  B3                   -  TX(J)
      C92  =     A2*  U2-  A3                   -  TY(J)
      C51  =     4.0*  B3  -  C52
      C61  =     4.0*  A3  -  C62
      C81  =   -4.0*  B2  -  C82
      C91  =   -4.0*  A2  -  C92
      DO 250 L=1,3
      Q11  =  Q(L,I)
      Q22  =  Q(L,J)
      Q33  =  Q(L,K)
      Q12  =  Q(L,I+3)
      Q23  =  Q(L,J+3)
      Q31  =  Q(L,K+3)
      Q1   =  Q22  -  Q33
      Q2   =  Q22  -  Q23
      Q3   =  Q33  -  Q23
      Q4   =  Q23  +  Q1
      Q5   =  Q23  -  Q1
  250 CV(L)  =   (-6.*Q11+3.*((U3-W2)*Q1+(U3+W2)*Q23))*W(I)
     1         +  (6.*Q22+3.*W3*Q4)*W(J)  +  (6.*Q33+3.*U2*Q5)*W(K)
     2         +((C21*Q1+C22*Q23+4.*(B2*Q31-B3*Q12))*RX(I)
     3         +  (C31*Q1+C32*Q23+4.*(A2*Q31-A3*Q12))*RY(I)
     4         +  (C51*Q22+C52*Q3)*RX(J)  +  (C61*Q22+C62*Q3)*RY(J)
     5         +  (C81*Q33+C82*Q2)*RX(K)  +  (C91*Q33+C92*Q2)*RY(K)
     6         +   Q5*RH(J)  +  Q4*RH(K))/2.
      DO 300 J=1,3
      BMT(I,J)  =  -FAC*(C(J,1)*CV(1)+C(J,2)*CV(2)+C(J,3)*CV(3))
  300 CONTINUE
      RETURN
      END
      SUBROUTINE STRESS(STR,B,D,NEQB,LB,LL,NEQ,NBLOCK)
C
C     COMPUTATION OF STATIC ELEMENT STRESSES
C                                                                       STRES   2
      DIMENSION D(NEQ,LB),B(NEQB,LL),STR(4,LL)                          STRES   3
C
      COMMON /JUNK/  LT,LH
C                                                                       STRES   9
      DO 50  L=1,LL
      DO 50  I=1,4
   50 STR(I,L)=1.0
      NT=(LL-1)/LB +1                                                   STRES  11
      LH=0                                                              STRES  12
      REWIND 3                                                          STRES  13
C                                                                       STRES  14
      DO 1000 II=1,NT                                                   STRES  15
C                                                                       STRES  16
      LT =LH+1                                                          STRES  17
      LLT=1-LT                                                          STRES  18
      LH=LT+LB-1                                                        STRES  19
      IF(LH.GT.LL) LH=LL                                                STRES  20
C                                                                       STRES  21
C     MOVE DISPLACEMENTS INTO CORE FOR LB LOAD CONDITIONS               STRES  22
C                                                                       STRES  23
      REWIND 2                                                          STRES  24
      NQ=NEQB*NBLOCK                                                    STRES  26
      DO 200 NN=1,NBLOCK                                                STRES  27
      READ (2) B                                                        STRES  28
      N=NEQB                                                            STRES  29
      IF (NN.EQ.1) N=NEQ-NQ+NEQB                                        STRES  30
      NQ=NQ-NEQB                                                        STRES  31
      DO 200 J=1,N                                                      STRES  32
      I=NQ+J                                                            STRES  33
      DO 200 L=LT,LH                                                    STRES  34
      K=L+LLT                                                           STRES  35
  200 D(I,K)=B(J,L)                                                     STRES  36
      LK=LH-LT+1                                                        STRES  37
C                                                                       STRES  38
C     CALCULATE STRESSES FOR ALL ELEMENTS FOR LB LOAD CONDITIONS        STRES  39
C                                                                       STRES  40
      REWIND 10
      READ  (10) NUMPL
      CALL SHL   (NUMPL)
 1000 CONTINUE                                                          STRES116
C                                                                       STRES117
      RETURN                                                            STRES118
      END                                                               STRES123
      SUBROUTINE STRSC(STR,D,NEQ,NTAG)
C
      DIMENSION STR(4,1),D(NEQ,1)
C
      COMMON /EM/       NS,ND,LM(24),B(12,24),TI(12,4)
      COMMON /JUNK/ LT,LH,L,SG(20), TH
C
      IF(NTAG.EQ.0) GO TO 800
      LL=L-LT+1
      DO 300  I=1,NS
      SG(I)=0.0
      DO 300  J=1,4
  300 SG(I)=SG(I)+TI(I,J)*STR(J,L)
      DO 500  J=1,ND
      JJ=LM(J)
      IF(JJ.EQ.0) GO TO 500
      DO 400  I=1,NS
  400 SG(I)=SG(I)+B(I,J)*D(JJ,LL)
  500 CONTINUE
      GO TO 900
C
  800 READ (10) ND,NS,(LM(I),I=1,ND),((B(I,J),I=1,NS),J=1,ND),
     1          ((TI(I,J),I=1,NS),J=1,4), TH
C
  900 RETURN
      END
      SUBROUTINE SHL (NUME)
      COMMON A(1)
      COMMON/ELPAR/ N1,N3,NEQ
      COMMON /JUNK/ LT,LH,L,SIG(20), TH
      IWARN=0
      LLT=LT
      LLH=LH
      PRINT 2002
      REWIND 14
      DO 800  MM=1,NUME
      CALL STRSC (A(N1),A(N3),NEQ,0)
      DO 800 L=LLT,LLH
      CALL STRSC (A(N1),A(N3),NEQ,1)
      TH=1.0/TH
      TH=TH*TH
      DO 700  I=4,6
  700 SIG(I)=-6.0*SIG(I)*TH
      DO 705  I=7,8
      SIG(I)  =SIG(I-6)-SIG(I-3)
      SIG(I+3)=SIG(I-6)+SIG(I-3)
  705 CONTINUE
      SIG( 9) = SIG(3)+SIG(6)
      SIG(12) = SIG(3)-SIG(6)
      SIGA=(SIG(7)+SIG(8))/2.
      SIG(13)=SIGA+(((SIG(7)-SIG(8))/2.)**2+SIG(9)**2)**0.5
      SIG(14)=SIGA-(((SIG(7)-SIG(8))/2.)**2+SIG(9)**2)**0.5
      SIG(15)=0.5*ATAN((2.*SIG(9))/(SIG(7)-SIG(8)))
      SIGB=(SIG(10)+SIG(11))/2
      SIG(16)=SIGB+(((SIG(10)-SIG(11))/2.)**2+SIG(12)**2)**0.5
      SIG(17)=SIGB-(((SIG(10)-SIG(11))/2.)**2+SIG(12)**2)**0.5
      SIG(18)=0.5*ATAN((2*SIG(12))/(SIG(10)-SIG(11)))
      WRITE(14) MM,(SIG(I),I=7,9),(SIG(I),I=13,15),
     1(SIG(I),I=10,12),(SIG(I),I=16,18)
      PRINT 3002, MM,(SIG(I),I=1,12)
  800 CONTINUE
      REWIND 14
      PRINT 2003
      DO 900 J=1,NUME
      READ(14) MM,(SIG(I),I=7,9),(SIG(I),I=13,15),
     1(SIG(I),I=10,12),(SIG(I),I=16,18)
      VMU=SQRT(0.5*(SIG(13)**2+SIG(14)**2+(SIG(13)-SIG(14))**2))
      VML=SQRT(0.5*(SIG(16)**2+SIG(17)**2+(SIG(16)-SIG(17))**2))
      IF(VMU.GT.36000.0) IWARN=1
      IF(VML.GT.36000.0) IWARN=1
      PRINT 3003,MM,(SIG(I),I=7,9),(SIG(I),I=13,15),VMU,
     1(SIG(I),I=10,12),(SIG(I),I=16,18),VML
900   CONTINUE
      IF(IWARN.EQ.1) PRINT 4000
C
      RETURN
C
2003  FORMAT( 1H1,' PRINCIPAL SHELL ELEMENT STRESSES',//,' ELEMENT
     1 COMBINED STRESS COMPONENTS',5X,'PRINCIPAL STRESS COMPONENTS',5X,'
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      2PRINCIPAL DIRECTION',8X,'VON MISES',/,' NUMBER',11X,'XX          YY
      3        XY',13X,'S1',10X,'S2',18X,'THETA',17X,'STRESS',/)
 3003  FORMAT(I5,4X,'(+)',3F10.1,5X,F10.1,2X,F10.1,14X,F8.4,14X,F9.1,/,
      19X,'(-)',3F10.1,5X,F10.1,2X,F10.1,14X,F8.4,14X,F9.1)
  2002 FORMAT (24H1 SHELL ELEMENT STRESSES//
      1  8H ELEMENT,4X, 26HMEMBRANE STRESS COMPONENTS,5X,
      2 25HBENDING STRESS COMPONENTS,9X,26HCOMBINED STRESS COMPONENTS,
      3/ 8H  NUMBER,7X,3HSXX,7X,3HSYY,7X,3HSXY,7X,3HMXX,7X,3HMYY,7X,
      4  3HMXY,6X,29H        XX          YY          XY,/)
  3002 FORMAT (I8,6F10.1,2X,3H(+),3F10.1,/,68X,2X,3H(-),3F10.1)
 4000  FORMAT(///,' • • • PLATE STRESS WARNING-SOME ELEMENTS ARE STRESSED
      1',/,       '       ABOVE 36000 PSI. SEE COLUMN OF VON MISES STRESS
      2',/,       '       COMPONENTS.')
       END
      SUBROUTINE BUCKLE(NBM,E,G,FAC)
C     BUCKLE COMPUTES A DEFLECTION CURVE BY THE UNIT LOAD METHOD
C     MOMENTS ARE INCREASED BY AXIAL FORCES.  DEFLECTION CALCULATIONS ARE
C     ITERATED TO SEE IF THE DEFLECTION CURVE CONVERGES OR DIVERGES.
C     NITER IS THE NUMBER OF ITERATIONS USED.  NINCR IS THE NUMBER OF
C     INCREMENTS THE BUCKLING MEMBER IS DIVIDED INTO TO APPROXIMATE THE
C     UNIT LOAD INTEGRAL.  NINCR OCCURS IN A PARAMETER STATEMENT IN THE
C     DRIVER PROGRAM
C     NBM IS THE NUMBER OF BUCKLING MEMBERS
C     NEP1,NEP2 ARE NODAL NUMBERS AT ENDS OF A BUCKLING MEMBER
C     NM1,NM2 ARE BEAM MEMBERS CONTAINING NEP1,NEP2 RESPECTIVELY
C     BLEN IS THE LENGTH OF THE BUCKLING MEMBER
C
      PARAMETER NITER=25,NINCR=12
      REAL IX,IY,IZ,L
      DIMENSION YY(NINCR),ZZ(NINCR),RMY(NINCR),RMZ(NINCR),UM(NINCR,NINCR
     1),YD(NITER),ZD(NITER),YSTORE(NITER),ZSTORE(NITER),FF(6)
      COMMON/BUCKL/IY(100),IZ(100),X(100),Y(100),Z(100),JJ(100),JK(100),
     1L(100),WY(100),WZ(100),IND1(5),IND2(5),URMY(5,NINCR),URMZ(5,NINCR)
     2,NI1(5),NI2(5),F(100),R(100,9),AX(100),IX(100),WX(100),YSTRS(100)
      COMMON/SOLN/DJ(600),AMR(12),JAK(12),TITLE(20)
      DIMENSION SM(12,12),SMR(12,12)
      PI=3.141592654
      DO 7000 JI=1,NBM
      READ(5,7702) NEP1,NEP2,NM1,NM2
      DELX=X(NEP2)-X(NEP1)
      DELY=Y(NEP2)-Y(NEP1)
      DELZ=Z(NEP2)-Z(NEP1)
      BLEN=SQRT(DELX*DELX+DELY*DELY+DELZ*DELZ)
      NI1(JI)=NM1
      NI2(JI)=NM2
      IF(NEP1.NE.JJ(NM1).AND.NEP1.NE.JK(NM1))GO TO 7100
      GO TO 7101
 7100 WRITE(6,7700) JI
      GO TO 7000
 7101 I1=0
      JT1=0
C
C     INDICATE WHICH END OF THE BEAM MEMBER IS THE END OF THE
C     BUCKLING MEMBER
C
      IF(JJ(NM1).EQ.NEP1)I1=1
      IF(JK(NM1).EQ.NEP1)JT1=1
      I=NM1
C
C     COMPUTE MEMBER STIFFNESS MATRIX FOR MEMBER I
C
      J1=6*JJ(I)-5
      J2=6*JJ(I)-4
      J3=6*JJ(I)-3
      J4=6*JJ(I)-2
      J5=6*JJ(I)-1
      J6=6*JJ(I)
      K1=6*JK(I)-5
      K2=6*JK(I)-4
      K3=6*JK(I)-3
      K4=6*JK(I)-2
      K5=6*JK(I)-1
      K6=6*JK(I)
      GY=(6.*F(I)*E*IY(I))/(G*AX(I)*L(I)**2)
      GZ=(6.*F(I)*E*IZ(I))/(G*AX(I)*L(I)**2)
      CFY1=1./(1.+2.*GY)
      CFZ1=1./(1.+2.*GZ)
      CFY2=(1.+GY/2.)*CFY1
      CFZ2=(1.+GZ/2.)*CFZ1
      CFY3=(1.-GY)*CFY1
      CFZ3=(1.-GZ)*CFZ1
      SCM1=(E*AX(I))/L(I)
      SCM2=(12.*E*IZ(I)*CFZ1)/L(I)**3
      SCM3=(6.*E*IZ(I)*CFZ1)/L(I)**2
      SCM4=(12.*E*IY(I)*CFY1)/L(I)**3
      SCM5=(6.*E*IY(I)*CFY1)/L(I)**2
      SCM6=(G*IX(I))/L(I)
      SCM7=(4.*E*IY(I)*CFY2)/L(I)
      SCM8=(2.*E*IY(I)*CFY3)/L(I)
      SCM9=(4.*E*IZ(I)*CFZ2)/L(I)
      SCM10=(2.*E*IZ(I)*CFZ3)/L(I)
      SM(1,1)=SCM1
      SM(7,7)=SCM1
      SM(1,7)=-SCM1
      SM(2,2)=SCM2
      SM(8,8)=SCM2
      SM(2,8)=-SCM2
      SM(2,6)=SCM3
      SM(2,12)=SCM3
      SM(6,8)=-SCM3
      SM(8,12)=-SCM3
      SM(3,3)=SCM4
      SM(9,9)=SCM4
      SM(3,9)=-SCM4
      SM(3,5)=-SCM5
      SM(3,11)=-SCM5
      SM(4,4)=SCM6
      SM(4,10)=-SCM6
      SM(10,10)=SCM6
      SM(5,5)=SCM7
      SM(11,11)=SCM7
      SM(5,11)=SCM8
      SM(6,6)=SCM9
      SM(12,12)=SCM9
      SM(9,11)=SCM5
      SM(5,9)=SCM5
      SM(6,12)=SCM10
      DO 204 II=2,12
      III=II-1
      DO 204 JJJ=1,III
  204 SM(II,JJJ)=SM(JJJ,II)
```

```
      DO 205 K=1,4
      DO 205 J=1,12
      SMR(J,3*K-2)=SM(J,3*K-2)*R(1,1)+SM(J,3*K-1)*R(1,4)+SM(J,3*K)
     1*R(1,7)
      SMR(J,3*K-1)=SM(J,3*K-2)*R(1,2)+SM(J,3*K-1)*R(1,5)+SM(J,3*K)
     1*R(1,8)
      SMR(J,3*K)=SM(J,3*K-2)*R(1,3)+SM(J,3*K-1)*R(1,6)+SM(J,3*K)*R(1,9)
  205 CONTINUE
      IF(JT1.EQ.1)GO TO 7021
C
C     FF(J) IS THE ARRAY OF MEMBER FORCES IN THE MEMBER COORDINATE SYSTEM
C     THEY ACT ON A NODE THAT IS AN ENDPOINT OF A BUCKLING MEMBER
C
      DO 7020 J=1,6
7020  FF(J)=SMR(J,1)*DJ(J1)+SMR(J,2)*DJ(J2)+SMR(J,3)*DJ(J3)+SMR(J,4)*
     1DJ(J4)+SMR(J,5)*DJ(J5)+SMR(J,6)*DJ(J6)+SMR(J,7)*DJ(K1)+SMR(J,8)
     2*DJ(K2)+SMR(J,9)*DJ(K3)+SMR(J,10)*DJ(K4)+SMR(J,11)*DJ(K5)+
     3SMR(J,12)*DJ(K6)
      GO TO 7022
7021  DO 7030 J=7,12
      JM=J-6
7030  FF(JM)=SMR(J,1)*DJ(J1)+SMR(J,2)*DJ(J2)+SMR(J,3)*DJ(J3)+SMR(J,4)*DJ
     1(J4)+SMR(J,5)*DJ(J5)+SMR(J,6)*DJ(J6)+SMR(J,7)*DJ(K1)+SMR(J,8)*DJ(K
     22)+SMR(J,9)*DJ(K3)+SMR(J,10)*DJ(K4)+SMR(J,11)*DJ(K5)+SMR(J,12)*DJ(
     3K6)
7022  CONTINUE
      DO 7040 IM=1,6
7040  FF(IM)=FF(IM)*FAC
C
C     COMPUTE MINIMUM MOMENT OF INERTIA
C
      EIY=AMIN1(IY(NM1),IY(NM2))
      EIZ=AMIN1(IZ(NM1),IZ(NM2))
C
C     COMPUTE 15 PERCENT OF THE EULER CRITICAL LOAD ABOUT THE WEAKEST
C     AXIS, FOR SIMPLE SUPPORTS
C
      PEUY=PI*PI*E*EIY/BLEN**2
      PEUZ=PI*PI*E*EIZ/BLEN**2
      PEULER=AMIN1(PEUY,PEUZ)
      PEULER=0.15*PEULER
      IF(I1.EQ.1)FF(1)=FF(1)
      IF(JT1.EQ.1)FF(1)=-FF(1)
      IF(FF(1).GT.PEULER)GO TO 7240
C
C     IF INDI=NO,P<15%P(CR), NO FURTHER CALCULATIONS
C     INDI=YES,P>15%P(CR), CHECK BUCKLING FOR THIS MEMBER
C
      INDI(J1)=' NO'
      GO TO 7000
7240  INDI(J1)='YES'
      TOTALY=0.0
      TOTALZ=0.0
      DEL=BLEN/NINCR
```

```
C
C     CHECK FOR YIELDING BY AXIAL STRESS ONLY
C
      PAXIAL=FF(I)/AX(NMI)
      IF(ABS(PAXIAL).GT.YSTRS(NMI)) GO TO 7000
C
C     COMPUTE THE MOMENTS ALONG A BUCKLING MEMBER DUE TO MEMBER FORCES
C     RMY AND RMZ ARE ORIGINAL MOMENTS, URMY AND URMZ ARE UPDATED MOMENTS
C     INCLUDING THE AXIAL FORCE EFFECT
C
      DO 5 M=1,NINCR
      RM=M
      DL=((RM-0.5)/NINCR)*BLEN
      IF(JTI.EQ.1)GO TO 25
      RMY(M)=-FF(5)-DL*FF(3)-WZ(I)*DL*DL*0.5
      RMZ(M)=-FF(6)+DL*FF(2)+WY(I)*DL*DL*0.5
      GO TO 35
25    RMY(M)=-FF(5)+DL*FF(3)+WZ(I)*DL*DL*0.5
      RMZ(M)=-FF(6)-DL*FF(2)-WY(I)*DL*DL*0.5
35    URMY(JI,M)=RMY(M)
      URMZ(JI,M)=RMZ(M)
      TOTALY=TOTALY+ABS(RMY(M))
5     TOTALZ=TOTALZ+ABS(RMZ(M))
C
C     IF TOTALY OR TOTALZ ARE ZERO THE DEFLECTIONS BY THE UNIT LOAD
C     METHOD WOULD BE ZERO REGARDLESS OF THE VALUE OF P.  A SMALL
C     INITIAL MOMENT IS APPLIED TO CHECK FOR BUCKLING IF NO MOMENT IS
C     ACTING DURING THE INITIAL STEP
C
      IF(TOTALY.LT.0.1)GO TO 1
7     CONTINUE
      IF(TOTALZ.LT.0.1)GO TO 2
      GO TO 6
1     DO 3 K=1,NINCR
      RMY(K)=5.0
3     URMY(JI,K)=5.0
      GO TO 7
2     DO 4 K=1,NINCR
      RMZ(K)=5.0
4     URMZ(JI,K)=5.0
6     INDY=0
      INDZ=0
C
C     COMPUTE SMALL MOMENT CURVE FOR UNIT LOAD CALCULATIONS
C     UM(K,J) IS THE MOMENT AT J DUE TO A UNIT LOAD AT K
C
      DO 10 K=1,NINCR
      RK=K
      DL=((RK-0.5)/NINCR)*BLEN
      RI=(BLEN-DL)/BLEN
      DO 10 J=1,NINCR
      RJ=J
      UM(K,J)=RI*(RJ-0.5)*(BLEN/NINCR)
      IF(J.LT.K)GO TO 10
```

```
             XX=RJ-RK
             UM(K,J)=UM(K,J)-XX*(BLEN/NINCR)
      10     CONTINUE
             00 100 I=1,NITER
             00 12 LJ=1,NINCR
             YY(LJ)=0.0
      12     ZZ(LJ)=0.0
      C
      C      YY AN0 ZZ ARE 0EFLECTIONS
      C      LOOPS 13 AN0 14 COMPUTE THE DEFLECTION CURVE BY THE UNIT LOA0 METHOD
      C
             00 14 J=1,NINCR
             00 13 K=1,NINCR
             YY(J)=YY(J)+UM(J,K)*URMZ(JI,K)*0EL/(E*EIZ)
      13     ZZ(J)=ZZ(J)+UM(J,K1*URMY(JI,K)*0EL/(E*EIY)
             URMY(JI,J)=RMY(J1+FF(I)*ZZ(J)
      14     URMZ(JI,J)=RMZ(J)+FF(I)*YY(J)
      C
      C      YSTORE AN0 ZSTORE ARE DEFLECTIONS OF THE MI0POINT OF THE SIXTH
      C      INCREMENT.  Y0 AN0 Z0 ARE THE 0IFFERENCES IN TWO SUCCESSIVE VALUES
      C      Y0 AND Z0 ARE USE0 TO CHECK FOR 0IVERGENCE/CONVERGENCE
      C
             YSTORE(I)=YY(6)
             ZSTORE(I1=ZZ(6)
             YD(I)=YSTORE(I)
             Z0(I)=ZSTORE(I1
             IF(I.EQ.1)GO TO 100
             YD(I)=ABS(YSTORE(I11-ABS(YSTORE(I-1)1
             ZD(I)=ABS(ZSTORE(I11-ABS(ZSTORE(I-111
             IF(Y0(I).GT.YD(I-11)INDY=INOY+1
             IF(ZD(I1.GT.Z0(I-1))INOZ=INOZ+1
             IF(INOY.GT.91GO TO 110
             IF(INOZ.GT.91GO TO 112
             IN02(JI)=' NO   '
             GO TO 100
      C
      C      IN02'NO, MEMBER 0I0 NOT BUCKLE
      C      IN02=YES, MEMBER OID BUCKLE
      C
      110    IND2(JI1='YES,Z'
             GO TO 100
      112    IN02(JI)='YES,Y'
      100    CONTINUE
      7000   CONTINUE
      7700   FORMAT(1H ,'INPUT ERROR IN BUCKLING MEMBER',I3)
      7702   FORMAT(4I5)
      7802   FORMAT(8F10.2)
             RETURN
             EN0
      SUBROUTINE PLOTS(IADV,NJ,MK,NUMPL,Y,Z,X,JJ,JK,THETA,PHI,IHED,ANGL)
      DIMENSION N(10),JJ(1),JK(1),IHED(1),ANGL(1)
      DIMENSION X(1),Y(1),Z(1),ICON(500,2)
      COMMON/PLOT/LP1(150),LP2(150),LP3(150),LP4(150)
C  THIS ROUTINE SETS UP THE INPUT FOR THE ROUTINE WHICH DOES THE PLOTTING.
C  THE KIND OF PLOT IS DETERMINED FROM THE INPUT AND MAY BE EITHER ALL BEAM,
C  ALL PLATES, BOTH BEAM AND PLATES - LOADED OR UNLOADED.  UNIQUE CONNECTIONS
C  ARE DEVELOPED FOR THE PLATES AND STORED IN THE ICON ARRAY.
C
C
C  THE CALLING ARGUMENTS TO THIS ROUTINE ARE AS FOLLOWS:
C
C     IADV - FRAME ADVANCE  0= ADVANCE,  1= HOLD FRAME
C
C     NJ - NUMBER OF JOINTS; DIMENSION OF X,Y,Z.
C
C     MK - NUMBER OF BEAM ELEMENTS.
C
C     NUMPL - NUMBER OF PLATES.
C
C     X,Y,Z - CO-ORDINATES OF THE JOINTS.
C
C     JJ,JK - BEAM NODES.
C
C     THETA - THE ANGLE ABOUT THE HORIZONTAL PLANE.  THIS IS THE POSITION
C     OF THE VIEWER RELATIVE TO THE PLOT.  IN A RIGHT-HANDED AXIS SYSTEM, THETA
C     OF 0 DETERMINES A VIEW DOWN THE -Y AXIS.  THETA OF 90 DEGREES IS A VIEW
C     DOWN THE +X AXIS.  THETA OF 180 DEGREES IS A VIEW DOWN THE +Y AXIS.
C     FOR MOST APPLICATIONS THETA EQUAL 120 DEGREES IS RECOMENDED.  THIS
C     GIVES A VIEW ONTO THE X-Y QUADRANT.
C
C     PHI - IS THE ELEVATION ANGLE WITH THE Z AXIS.  THIS ANGLE MAY RANGE
C     FROM -90 DEGREES TO +90 DEGREES.  PHI GREATER THAN 0 IMPLIES A VIEW
C     FROM THE TOP OF THE PLOT.  PHI LESS THAN 0 GIVES AN UNDERSIDE VIEW.
C     IN MOST INSTANCES PHI EQUAL 90 DEGREES IS RECOMMENDED.
C
C
C  EVERY ATTEMPT HAS BEEN MADE TO KEEP THIS PLOT PACKAGE UNIVERSAL IN ITS
C  USE OF PLOTTERS.  ONLY FUNDAMENTAL ROUTINES OF THE PLOTTING SYSTEM HAVE
C  BEEN USED AND ARE DETAILED AT THEIR CALL SEQURNCE AS TO DISCRIPTION SO
C  THAT THESE CALLS MAY BE EASILY RLPLACED WITH CALLS PERTINENT TO
C  ANOTHER SYSTEM.
C
C  MANY OF THE PLOT SYSTEM ROUTINES WILL BE FULLY COMPATIBLE WITH OTHER
C  MACHINES AS EY STAND.  THE ONLY ATTENTION NECESSARY FOR CONVERSION IS TO TH
C  THE FOLLOWING CALLS.
C
C
C     SETUPV - THE SET UP ROUTINE TO ACTIVATE PLOTTING.  THIS ROUTINE IS
C     USUALLY UNIQUE TO EACH COMPUTER INSTALLATION.
C
C     FRAMEV - FRAME ADVANCE ROUTINE.
C
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C      PLOTCV - ROUTINE WHICH PLOTS A CHARACTER.
C
C      LINEUV - ROUTINE WHICH DRAWS A LINE BETWEEN TWO POINTS.
C
C      MODEV - ROUTINE WHICH CONVERTS FROM USER CO-ORDINATES TO RASTER
C      CO-ORDINATES.
C
C      TYPEV - ROUTINE WHICH TYPES A LINE OF PRINTED INFORMATION ON THE PLOT.
C
C      FINSHV - ROUTINE WHICH DENOTES THE PLOT FILE IS FINISHED. USUALLY UNIQUE.
C               IS LOCATED IN THE MAIN PROGRAM WHICH CALL THIS ROUTINE.
C
C  THE ARGUEMENTS ARE DESCRIBED IN DETAIL AT THE CALLS.
C
C
       NPTS=NJ
       IBEAMS=0
C  THE FOLLOWING FOUR CARDS ARE THE CORNERS OF THE GREATEST ALLOWABLE PLOT
C  AREA.  IN PRACTICE MOST PLOTS WILL NEVER REACH THESE LIMITS.
C
C  TO CONVERT TO ANOTHER PLOTTING SYSTEM - REPLACE THESE RASTER COUNTS WITH
C  LIMITS SUITABLE TO THE NEW SYSTEM.
      JCON=0
       IL=100
       IR=800
       JB=130
       JT=950
  15   CONTINUE
       IF(MK.EQ.0) GO TO 28
C
C  THE PLOT HAS BEAMS.
C
       NCON=MK
       IBEAMS=1
       IF(IBEAMS.EQ.0) GO TO 28
       DO 20 I=1,NCON
       ICON(I,1)=JJ(I)
       ICON(I,2)=JK(I)
   20  CONTINUE
  29   JCON=NCON
  28   CONTINUE
       IF(NUMPL.EQ.0) GO TO 500
C
C  THE PLOT HAS PLATES.
C
C  NCON NON-ZERO GIVES BOTH BEAMS AND PLATES.
C
C
C  LP1...LP4 IN COMMON BLOCK ARE THE PLATE NODES.
C
C  THE FOLLOWINF CODE GENERATES THE UNIQUE CONNECTION FOR PLATES.
C
  30   DO 60 IN=1,NUMPL
       N(1)=LP1(IN)
      N(2)=LP2(IN)
      N(3)=LP3(IN)
      N(4)=LP4(IN)
   35 LP=3
      IF(N(4).EQ.0) LP=2
      DO 50 K=1,LP
      M=JCON+K
      ICON(M,1)=N(K)
      ICON(M,2)=N(K+1)
      MM=M-1
      IF(M.LT.3) GO TO 50
      DO 40 IM=1,MM
      IF(ICON(IM,2).NE.ICON(M,2))GO TO 40
      IF(ICON(IM,1).NE.ICON(M,1)) GO TO 40
      JCON=JCON-1
      GO TO 50
   40 CONTINUE
      DO 41 IM=1,MM
      IF(ICON(IM,2).NE.ICON(M,1)) GO TO 41
      IF(ICON(IM,1).NE.ICON(M,2)) GO TO 41
      JCON=JCON-1
      GO TO 50
   41 CONTINUE
   50 CONTINUE
      LP=LP+1
      M=JCON+LP
      ICON(M,1)=N(1)
      ICON(M,2)=N(LP)
      DO 51 IM=1,MM
      IF(ICON(IM,2).NE.ICON(M,2))GO TO 51
      IF(ICON(IM,1).NE.ICON(M,1)) GO TO 51
      JCON=JCON-1
      GO TO 53
   51 CONTINUE
      DO 52 IM=1,MM
      IF(ICON(IM,2).NE.ICON(M,1)) GO TO 52
      IF(ICON(IM,1).NE.ICON(M,2)) GO TO 52
      JCON=JCON-1
      GO TO 53
   52 CONTINUE
   53 JCON=JCON+LP
   60 CONTINUE
  450 NCON=JCON
  500 CONTINUE
C
C  SETUPV ARGUMENTS DESCRIPTION:
C      'COPIES',1     - ONE COPY OF PLOT.
C                     - 0 COPIES MAY BE USED FOR CHECKOUT.
C                     - 2...N MAY BE USED FOR MULTIPLE COPIES.
C
C      'MUST GOULD'   - USE GOULD PLOTTER.
C                     - 'MUST CALCOMP' USES THE CALCOMP PLOTTER.
      IF(IB4.EQ.0)CALL SETUPV('COPIES',1,'MUST GOULD')
      IB4=1
  650   CALL PLOTIT(NPTS,X,Y,Z,THETA,PHI,ICON,NCON,IADV)
  750   CONTINUE
C
C  TYPEV ARGUMENTS DESCRIPTION:
C     'IHED' - ARRAY OF INFORMATION TO BE PRINTED.
C
C     80 - NUMBER OF CHARACTERS IN IHED
C
C     480,100 - ARE RASTER CO-ORDINATES OF FIRST CHARACTER TO APPEAR AT CENTER.
C
C     'CENTER' - IMPLIES POSITIONING BEGINS AT CENTER OF CHARACTER STRING
C     IN IHED.
C
        CALL TYPEV(IHED,80,450,100,'CENTER')
        CALL TYPEV(ANGL,24,450,75,'CENTER')
        RETURN
        END
```

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      SUBROUTINE PLOTIT(IMAX,X,Y,Z,THETA,PHI,ICON,NCON,ILOAD)
      DIMENSION X(1),Y(1),Z(1),ICON(500,2)
      DIMENSION PY(100),PZ(100)
C
C  THE FOLLOWING CODE RESOLVES THE THREE-DIMENSIONAL CO-ORDINATES INTO THE
C  TWO-DIMENSIONAL PLACE AS VIEWED FROM THE DESIRED DIRECTION.
C     IMAX - NUMBER OF JOINTS OR POINTS IN X,Y,Z.
C
C     THETA - AZIMUTH ANGLE - PREVIOUSLY DESCRIBED.
C
C     PHI - ELEVATION ANGLE - PREVIOUSLY DESCRIBED.
C
C     ICON - ARRAY OF UNIQUE CONNECTIONS.
C
C     NCON - NUMBER OF UNIQUE CONNECTIONS TO BE MADE BETWEEN NODES.
C
C     ILOAD - FRAME ADVANCE FLAG.  GENERALLY USED FOR SUPERIMPOSED PLOT FOR
C     LOADED ELEMENTS.
C
C
      D=5.0
      IF(ILOAD.NE.1) CALL FRAMEV
      IF(ILOAD.EQ.1) GO TO 353
C  SET UP PLOT AREA AND MARGIN LIMITS
      IL=100
      IR=800
      JB=130
      JT=950
      XMAX = -1000.0
      XMIN = 1000.0
      YMAX = -1000.0
      YMIN = 1000.0
      ZMAX = -1000.0
      ZMIN = 1000.0
      DO 316 I=1,IMAX
      IF( X(I).GT. XMAX) XMAX = X(I)
      IF( X(I).LT. XMIN) XMIN = X(I)
      IF( Y(I).GT. YMAX) YMAX = Y(I)
      IF( Y(I).LT. YMIN) YMIN=Y(I)
      IF( Z(I) .LT. ZMIN) ZMIN = Z(I)
      IF(Z(I) .GT. ZMAX) ZMAX=Z(I)
  316 CONTINUE
      XBAR=.5*(XMIN+XMAX)
      YBAR=.5*(YMIN+YMAX)
      ZBAR=.5*(ZMAX+ZMIN)
C
C  DEVELOPE THE ROTATIONAL ANGLES FOR THE DESIRED VIEW.
C
      PI=3.14159265
      THR=THETA*PI/180.
      PHR=PHI*PI/180.
      CTH=COS(THR)
      STH=SIN(THR)
      SPH=SIN(PHR)
      CPH=COS(PHR)
      B=-CTH*CPH
      A=STH*CPH
      C=SPH
      DRAT=D*(XMAX-XMIN)
      XV=XMIN+DRAT*A
      YV=YMIN+DRAT*B
      IF (A.GT.0) XV=XMAX+DRAT*A
      IF (B.GT.0) YV=YMAX+DRAT*B
      ZV=ZBAR+DRAT*C
      CALL PLAN1(XBAR,YBAR,ZV,XV,YV,ZV,1.0)
      CALL PLANE(XMIN,YMIN,ZMAX,DUM,XPMAX,YPMAX)
C
      XPMIN=XPMAX
      YPMIN=YPMAX
      ZT=ZMAX
  33  CONTINUE
       DO 34 I=1,4
      IF(I.EQ.1)CALL PLANE(XMIN,YMIN,ZT,DUM,XPT,YPT)
      IF(I.EQ.2)CALL PLANE(XMIN,YMAX,ZT,DUM,XPT,YPT)
      IF(I.EQ.3)CALL PLANE(XMAX,YMIN,ZT,DUM,XPT,YPT)
      IF(I.EQ.4)CALL PLANE(XMAX,YMAX,ZT,DUM,XPT,YPT)
      XPMIN=MIN(XPMIN,XPT)
      XPMAX=MAX(XPMAX,XPT)
      YPMIN=MIN(YPMIN,YPT)
      YPMAX=MAX(YPMAX,YPT)
34             CONTINUE
35             CONTINUE
      IF(ZT.LE.ZMIN) GO TO 352
      ZT=ZMIN
      GO TO 33
352            CONTINUE
C   CALCULATE SCALE FACTOR
          IMID=(IL+IR)/2
          JMID=(JB+JT)/2
          XMID=(XPMAX+XPMIN)*.5
          YMID=(YPMIN+YPMAX)*.5
          XRAT=(XPMAX-XPMIN)/(IR-IL)
          YRAT=(YPMAX-YPMIN)*CPH/(JT-JB)
          DELTA=MAX(XRAT,YRAT)*1000
C
C
C  THIS ROUTINE RELATES THE USER CO-ORDINATES WITH THE RASTER CO-ORDINATES
C  BY EQUATING THE FOUR CORNERS FOLLOWING 'EQUATE', WITH THE ARGUEMENTS
C  FOLLOWING 'WITH'.
      CALL MODEV('EQUATE',XMID-DELTA,XMID+DELTA,
     *   YMID-DELTA/CPH,YMID+DELTA/CPH,
     *  'WITH',IMID-1000,IMID+1000,JMID-1000,JMID+1000)
C
 353    CONTINUE
C
C     THE ROUTINE - PLANE
C  RESOLVES THE POINT IN THREE-DIMENSIONS DESCRIBED BY X,Y,Z INTO
```

```
C  THE PLANE PY, PZ.
C
C     PLOTCV - 1 DENOTES ONE CHARACTER TO BE PLOTTED AT UC PY(I), PZ(I),
C     AND THAT CHARACTER IS TO BE A '0'.
C
C     LINEUV - CONNECTS THE POINT DESCRIBED BY THE FIRST TWO ARGUEMENTS TO
C     THE POINT DESCRIBED BY THE LAST TWO ARGUEMENTS.

      DO 36 I=1,IMAX
      CALL PLANE(X(I),Y(I),Z(I),DUM,PY(I),PZ(I))
      IF(ILOAD.EQ.0) CALL PLOTCV(1,PY(I),PZ(I),'0')
      IF(ILOAD.EQ.1) CALL PLOTCV(1,PY(I),PZ(I),'*')
   36 CONTINUE
      DO 37 I=1,NCON
      IP1 = ICON(I,1)
      IP2 = ICON(I,2)
      CALL LINEUV(PY(IP1),PZ(IP1),PY(IP2),PZ(IP2))
  37   CONTINUE
                          SUBROUTINE PLANE(X,Y,Z,XP,YP,ZP)
      REAL A(3,4),XA(3),XB(3),LAMB,ZETA,LAMBSQ
C
      XA(1)=X
      XA(2)=Y
      XA(3)=Z
      DO 22 I=1,3
      XB(I)=A(I,4)
      DO 21 J=1,3
21    XB(I)=XB(I)+A(I,J)*XA(J)
22             CONTINUE
      XP=XB(1)
      YP=XB(2)/XP
      ZP=XB(3)/XP
               RETURN
C
         ENTRY    PLAN1(X1Q,X2Q,X3Q,X1V,X2V,X3V,D)
      ALPH=X1V-X1Q
      BETA=X2V-X2Q
      ZETA=X3V-X3Q
      LAMBSQ=ALPH**2+BETA**2
      GAMSQ=LAMBSQ+ZETA**2
      LAMB=SQRT(LAMBSQ)
      GAM=SQRT(GAMSQ)
      C=LAMB/GAM
      S=ZETA/GAM
      C1=ALPH/LAMB
      S1=BETA/LAMB
      IF (S1**2+C1**2.GT.0.5) GO TO 15
        S1=-1.0
        C1=0
15    A(1,1)=-C*C1
      A(1,2)=-C*S1
      A(1,3)=-S
      A(1,4)=C*C1*X1Q+C*S1*X2Q+S*X3Q+GAM
      A(2,1)=-S1*D
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      A(2,2)= C1*D
      A(2,3)= 0
      A(2,4)=(S1*X1Q-C1*X2Q)*D
      A(3,1)=-S*C1*D
      A(3,2)=-S*S1*D
      A(3,3)= C*D
      A(3,4)=(S*C1*X1Q+S*S1*X2Q-C*X3Q)*D
        RETURN
        END
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